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LITTLE BOW RIVER BASIN
STORAGE SITE INVESTIGATION
CONCEPTUAL DESIGN REPORT

May, 1985

Prepared For:

Alberta Environment
Planning Division

Prepared By:

W-E-R Engineering Ltd.

in association with

Thurber Consultants Ltd.

and

Nanuk Engineering and Development Ltd.



May 8, 1985

Alberta Environment
Planning Division
200 - 5 Avenue South
Lethbridge, Alberta
T1J 4C7

Attention: Mr. Sandy Larsen, P.Eng.

Re: Little Bow River Basin
Storage Site Investigation
Conceptual Design Report

Dear Mr. Larsen:

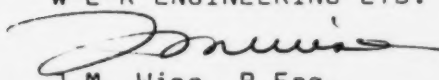
We are pleased to submit herewith five copies of our interim report entitled "Little Bow River Basin Storage Site Investigation - Conceptual Design Report", May, 1985.

W-E-R Engineering Ltd. wishes to acknowledge the involvement of Thurber Consultants Ltd. and Nanuk Engineering and Development Ltd. in providing the valuable geotechnical and hydrological analyses included herein.

This has been a most interesting and challenging assignment. We welcome any questions that may arise as a result of this work. Accordingly, we are now proceeding with the feasibility design phase of this investigation.

Yours very truly,

W-E-R ENGINEERING LTD.


J.M. Wise, P.Eng.
Vice - President

CHR:kb
w/encl.

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- C - PRELIMINARY COST ESTIMATE ANALYSIS
- D - RESERVOIR DAMAGES AND LAND ACQUISITION

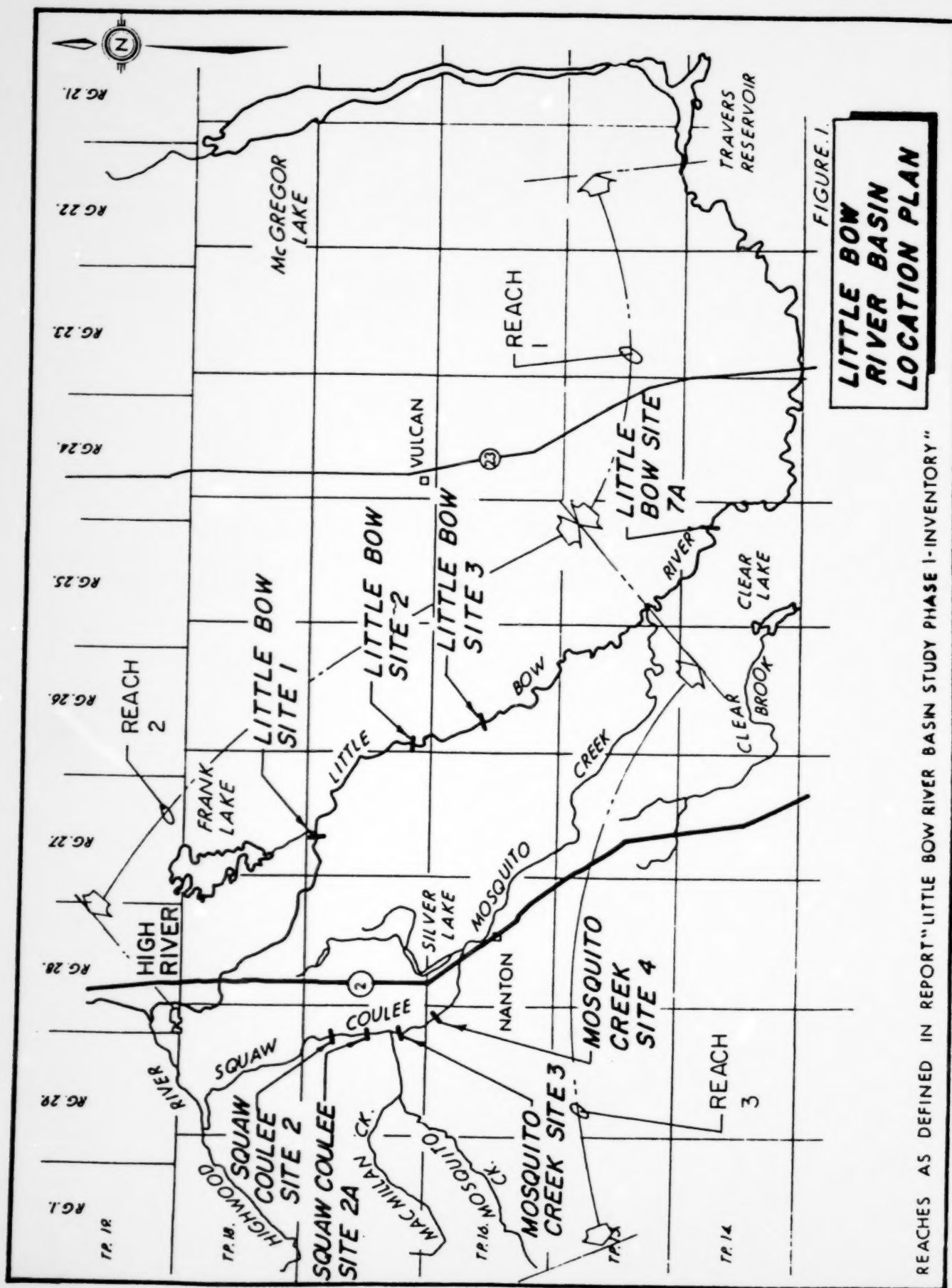


FIGURE 1.

LITTLE BOW RIVER BASIN LOCATION PLAN

REACHES AS DEFINED IN REPORT "LITTLE BOW RIVER BASIN STUDY PHASE I-INVENTORY"

1.0 INTRODUCTION

Irrigation water demand in the Little Bow River Basin has increased substantially in recent years and indications are that this trend is likely to continue. This increased use has coincided with a period of below normal stream flows. As a result, water shortages during peak demand periods have occurred, and are steadily becoming more frequent and more severe.

In order to formulate a comprehensive water management and licencing policy for the basin, Alberta Environment launched a basin planning study in 1982 which to date has involved a wide range of components dealing with various aspects of the overall problem. These background studies strongly recommended that the feasibility of constructing storage facilities in the Little Bow River Basin be investigated. W-E-R Engineering Ltd. was engaged in February, 1985 to conduct the current storage reservoir assessment in two stages.

The initial stage, described in this report, provides conceptual reservoir site analyses for comparative purposes. Previous studies by PFRA¹ and by W-E-R Engineering Ltd.² identified a total of eight reservoir alternatives, located as shown in Figure 1. Two of these are located on Squaw Coulee, two on Mosquito Creek, three on the Little Bow River above the confluence with Mosquito Creek, and one on the Little Bow below the confluence. A conceptual design and cost estimate was prepared for each of these sites, which enabled the selection of three primary sites for more detailed investigation to be carried out in a subsequent study.

1 - "Preliminary Report, Little Bow - Mosquito Creek Project", October, 1968

2 - "Preliminary Report, Storage Alternatives, Little Bow Basin", June, 1982

In accordance with the terms of reference as outlined in our proposal, this investigation is limited to storage maximization at the selected sites, on the basis of the current 30/10 operational guideline of Highwood River flows at the Little Bow and Squaw Coulee diversions (i.e. to the maximum physical capacities of the existing diversion system - 100 cfs in the Little Bow Canal and 60 cfs at the Squaw Coulee diversion).

This summary report compares each of the eight sites from the standpoint of water supply capability, geotechnical considerations, structure layout and design, reservoir damages, land acquisition, and costs of implementation. The study results have been summarized in the form of design layouts, pertinent data and a comparison spreadsheet at the back of the main report.

Details of each of the component studies which include hydrology, geotechnical, design and reservoir damage overviews are provided in Appendices A through D. On the basis of the conceptual investigations, recommendations for subsequent pre-design studies are presented.

2.0 HYDROLOGIC ASSESSMENT

2.1 Water Supply

Water supply studies were conducted to evaluate the effectiveness of each reservoir in terms of the total water supply that it would provide during the irrigation season. Throughout this stage of the study, the analyses were based only on diverted flows in accordance with existing operational guidelines, as set out in Scenario "E" by Hydrocon Engineering, up to the existing physical capacities of the diversion systems (100 cfs in the Little Bow Canal and 50 cfs in the Squaw coulee Diversion). Natural inflows, evaporation losses and channel losses were not considered. The study was based on the critical flow period of 1923 to 1938 in which two of the years had the worst and third lowest diversion potential in the period of record.

In accordance with the above-noted criteria, the maximum feasible reservoir sizes, limited by water supply considerations, were established as follows:

Little Bow Sites (above confluence)	27,500 ac.ft.
Squaw Coulee and Mosquito Creek Sites	21,000 ac.ft.
Site 7A (below confluence)	41,000 ac.ft.

These sizes of reservoirs are not optimum in terms of yield/storage ratios. A storage capacity of 15,000 to 20,000 ac.ft. will provide nearly equal water supply to the basin.

2.2 Flood Flows

The following floods were established for spillway design purposes based on preliminary hydrologic analysis using

methods from the Saskatchewan-Nelson Board report and transposition of floods from Willow Creek. This method was used for comparative purposes only, despite the physiographic differences in the two basins:

	<u>1:100 Instantaneous (cfs)</u>	<u>Mean Daily P.M.F. (cfs)</u>
Little Bow 1	3,840	7,200
Little Bow 2	7,100	16,725
Little Bow 3	8,890	18,060
Little Bow 7A	13,200	19,000
Mosquito Creek 3	10,740	15,010
Mosquito Creek 4	11,430	15,000
Squaw Coulee 2	2,980	5,600
Squaw Coulee 2A	3,190	5,940

-----WATER SUPPLY AND HYDROLOGY DETAILS IN APPENDIX A-----

3.0 GEOLOGICAL/GEOTECHNICAL OVERVIEW

3.1 Bedrock Geology

The Paskapoo Formation, composed of inter-bedded non-~~fine~~ fine shales, siltstones and sandstones, is the uppermost bedrock unit at each of the eight site alternatives. The bedrock is generally flat-lying and only moderately jointed or fractured, indicating favourable construction conditions.

3.2 Surficial Geology

The dominant surficial materials are glacial tills, composed primarily of mixtures of clay and gravel. Sands and gravels are abundant, occurring in esker, delta and kame deposits. Some post-glacial deposits are found primarily as alluvial and colluvial materials in floodplains and terraces.

3.3 Buried Valleys

A number of infilled pre-glacial valleys were identified in the study area. These buried valleys are of concern in that if infilled with extensive granular deposits, they represent a potential source of significant water losses from reservoirs located above them. This may also result in high groundwater pressures beneath the dam, which could present problems for structural integrity.

Three of the eight sites could be affected by buried valleys. These are Little Bow Site 2, Mosquito Creek Site 3, and the upstream reaches of Mosquito Creek Site 4.

3.4 Implications for Construction

With the possible exception of the buried valleys described

in the preceding section, no major geotechnical features that would preclude the construction of storage works, were identified in this assessment. Special measures would be required at most of the site locations to minimize seepage through granular flood plain deposits, and to a lesser extent, through fractured bedrock units in the abutments. Suitable construction materials are available in the immediate vicinity of most sites, with the exception of riprap and select granular material, which would have to be imported.

3.5 Embankment Designs

Based on the geotechnical overview, the embankments were designed with 20-foot wide crests, 4:1 or 4.5:1 upstream slopes and 3:1 downstream slopes. All of the embankments have key trenches and downstream pervious filters. Slope protection is provided by rock riprap on a gravel bed.

----- GEOLOGY/GEOTECHNICAL DETAILS IN APPENDIX B -----

4.0 CONCEPTUAL DESIGNS

4.1 General

Conceptual designs and cost estimates were prepared for each of the eight sites, as shown in Figures 5 through 12 and in Tables 1 through 8 (back of summary report). Detailed topographic and geotechnical information for Little Bow Site 1 and Mosquito Creek Site 4 was predicated on 1968 reports by PFRA, and used in the design study. For the remaining six reservoir alternatives, structure designs were based on 1:50,000 scale NTS sheets (25-foot contours), on available air photo coverage and on the geotechnical overviews conducted for this study.

4.2 Reservoir Sizing

Reservoirs were sized to either topographic or water supply maximum (based on current diversion guidelines), whichever controlled, in order to maximize the storage at each site.

Five of the eight reservoir alternatives - Little Bow Sites 1 and 2, Mosquito Creek Site 3 and Squaw Coulee Sites 2 and 2A, were designed to the maximum feasible elevation permitted by topographic conditions. The remaining three sites, Little Bow Sites 3 and 7A, and Mosquito Creek Site 4 could not be sized at the topographic maximum because of water supply limitations as described in Section 2.0. If however, in subsequent stages of the basin study, enlargement of the diversion works from the Highwood River is considered, the maximum size of these three reservoir alternatives may be re-examined.

A future study may also consider optimizing storage size

which is also discussed in the hydrology section contained in Appendix A.

4.3 Embankment Design

The embankment designs used in this conceptual study were based primarily on the geological and geotechnical overviews detailed in Appendix B. With the exception of the two sites drilled by PFRA in the 1960's, the geotechnical data is very limited and consequently the embankment designs may be considered conservative. For all site alternatives, allowance was made in the cost estimates for the installation of filters, key trenches, and adequate slope protection.

4.4 Structure Layouts

In view of the very limited topographic information available for six of the eight sites (NTS 25-foot contours), the structure layouts are very preliminary and have not been shown in Figures 2 to 9. For all eight reservoir alternatives, chute spillways are proposed together with gated conduit riparian outlet structures.

4.5 Spillways

Conceptual designs are based on reinforced concrete fixed-crest chute spillways sized to pass the routed 1:100 outflows as presented in Appendix A. In all cases the spillways will pass the safety-of-dam flood ($0.5 \times$ probable maximum flood) with one foot of freeboard remaining. This condition is in accordance with Alberta Environment's dam safety guidelines. In the subsequent pre-design studies, potential cost savings resulting from the use of a gated

chute spillway or a chute spillway/emergency earth spillway combination, will be evaluated for each site.

4.6 Riparian Outlet Works

Gated precast concrete conduit outlets are proposed for each of the reservoir alternatives. These structures would be utilized to divert normal streamflows during the construction period, and subsequently converted to permanent outlet works for irrigation and riparian releases. Riparian works were designed to provide 300 cfs releases at minimum reservoir levels for all sites.

4.7 Basis of Costing

Unit construction costs utilized in the preparation of cost estimates for this study were based on bid prices for recent tenders on similar storage projects as well as tender prices on recent major irrigation works in Southern Alberta.

----- MAIN WORKS COST DETAILS IN APPENDIX C -----

5.0 RESERVOIR COSTS

An assessment of land acquisition costs and reservoir damages was conducted for each of the eight reservoir sites included in the study. The reservoir cost phase of the study is considered to be preliminary in scope and is intended to provide order-of-magnitude costs to be used in the screening and comparison of alternative reservoir proposals.

The results are based primarily on existing topographic plans where available, 1:50,000 scale NTS maps and 1:30,000 scale 1983 air photo coverage.

5.1 Land Acquisition

In all cases, the areas required for reservoir land control are based on top-of-dam elevation to allow for reservoir erosion and wave action. Unit land prices were averaged at \$800 per acre for cultivated or irrigated land and \$300 per acre for pasture. A severance and acquisition factor of 25 percent was added.

5.2 Reservoir Damages

5.2.1 Roads and Bridges

The most significant damage item in this phase of the study is the cost of raising and improving existing market roads and bridges. In most cases it was assumed that the existing grid road would be retained, requiring expensive causeway-type embankments, armoured on both slopes, and relatively high bridges. In a few cases where it appeared feasible to re-route traffic, it was assumed that sections of existing

road would be abandoned. Municipal or provincial transportation authorities were not consulted at this stage. However, in subsequent phases of the study the question of road requirements should be examined in further detail.

5.2.2 Utilities

A major power transmission line crosses the Little Bow Site 2 reservoir. An allowance was made in the costs for special long-span support towers.

No pipelines were identified as crossing any of the reservoirs. This aspect should be examined more closely in future studies, and if existing pipelines are affected, ballasting or re-routing may be required.

5.2.3 Farm Buildings

The study assumed that any existing farm buildings could be moved to new locations outside the reservoir area. Based on studies conducted for Keho Lake, a relocation cost of \$50,000 for each set of farm buildings was assumed. A Hutterite colony that would be affected by Little Bow Site 2 was estimated at \$100,000.

----- RESERVOIR COST DETAILS IN APPENDIX D -----

6.0 CONCLUSIONS AND RECOMMENDATIONS

1. Little Bow Site 1

- is the most effective site on the Little Bow River upstream from the confluence in terms of cost versus firm water supply in the basin;
- approaches the hydrologic optimum capacity (based on current water supply);
- supplies Reach 1 and most of Reach 2.

Recommendation: Retain for further study in pre-design stage.

2. Little Bow Site 2

- is less effective than Little Bow Site 1 in terms of cost versus firm water supply;
- supplies less area in Reach 2 than Site 1;
- located on buried valley therefore geotechnical considerations of major concern;
- has much higher reservoir costs and total costs than Site 1.

Recommendation: Delete from further study.

3. Little Bow Site 3

- is less effective than Little Bow Site 1 in terms of cost versus firm water supply;
- supplies less area in Reach 2 than Site 2;
- has much higher reservoir costs and total costs than Site 1;
- storage limited by water supply, not topography.

Recommendation: Delete from current study but consider if diversions from the Highwood River are to be increased.

4. Little Bow Site 7A

- is the largest reservoir studied and is supplied by both diversions;
- provides largest water supply;
- supplies Reach 1 only;
- could supply Clear Lake by pump diversion;
- most economical site in terms of cost versus total storage.

Recommendation: Retain for further study in a subsequent investigation on confluence sites.

5. Mosquito Creek Site 3

- is least effective site in terms of cost versus both storage and water supply;
- is smallest reservoir and provides least water supply improvement;
- is supplied by Squaw Coulee Diversion plus Mosquito Creek;
- supplies Reach 1 and Reach 3;
- supplies Clear Lake by gravity diversion.

Recommendation: Delete from further study.

6. Mosquito Creek Site 4

- is more effective than any of the four Mosquito Creek/Squaw Coulee sites in terms of cost versus firm water supply;

- is supplied by Squaw Coulee Diversion plus Mosquito Creek,
- supplies Reach 1 and most of Reach 3,
- supplies Clear Lake by gravity diversion.

Recommendation: Retain for further study in pre-design stage.

7. Squaw Coulee Site 2

- is the most effective site in terms of cost versus firm water supply;
- has the lowest total cost;
- is supplied by Squaw Coulee Diversion only;
- supplies Reach 1 and Reach 3;
- supplies Clear Lake by pumping.

Recommendation: Retain for further study in pre-design stage.

8. Squaw Coulee Site 2A

- is much less effective than Squaw Coulee 2 in terms of cost versus both reservoir capacity and water supply improvement;
- is supplied by Squaw Coulee only;
- supplies Reach 1 and Reach 3;
- supplies Clear Lake by pump diversion.

Recommendation: Delete from further study.

Comments

From the above-listed comparison, three of the site proposals are recommended to be deleted from any further consideration, with Little Bow Sites 3 and 7A recommended for

future studies beyond the scope of the current investigations. Little Bow Site 1, Mosquito Creek Site 4 and Squaw Coulee Site 2 are the most attractive sites that are supplied by a single diversion system, and should be retained for pre-design studies which have been already authorized. This pre-design stage will examine the three site proposals in greater detail and provide more detailed cost estimates than are available at present.

The conceptual design studies did not consider the feasibility of constructing more than one reservoir (for example one reservoir on the Little Bow River and one on Mosquito Creek). Subsequent studies might address this aspect and compare the technical feasibility and water supply capability of a two-reservoir concept in comparison with a single large reservoir below the confluence such as Site 7A.

Finally, it should be noted that the study results as presented in this report are based on the current 10/30 diversion guideline of flows from the Highwood River. Should these guidelines be modified (increased) in the future, this would alter the results for at least three reservoir sites under consideration, namely, Little Bow Sites 3 and 7A, and Mosquito Creek Site 4.

STUDY RESULTS

TABLE 1
LITTLE BOW SITE 1

PROJECT DATA

Reservoir

Effective Drainage Area	30 mi ²
Full Supply Level (FSL)	3,290 ft.
Total Storage at FSL	17,250 ac.ft.
Live Storage	17,150 ac.ft.
Flooded Area at FSL	810 ac.
Safety-of-Dam Flood (0.5 probable maximum mean daily inflow)	3,600 cfs

Embankment

Top of Dam Elevation	3,299 ft.
Maximum Height	59 ft.
Volume of Fill	586,360 yds. ³

Spillway

Type of Spillway	Concrete Chute
Crest Elevation	3,290 ft.
Spillway Design Discharge	1,920 cfs
- (estimated 1:100 routed outflow)	
Safety-of-Dam Discharge	3,600 cfs
- (0.5 probable maximum mean daily inflow)	

Diversion and Outlet Works

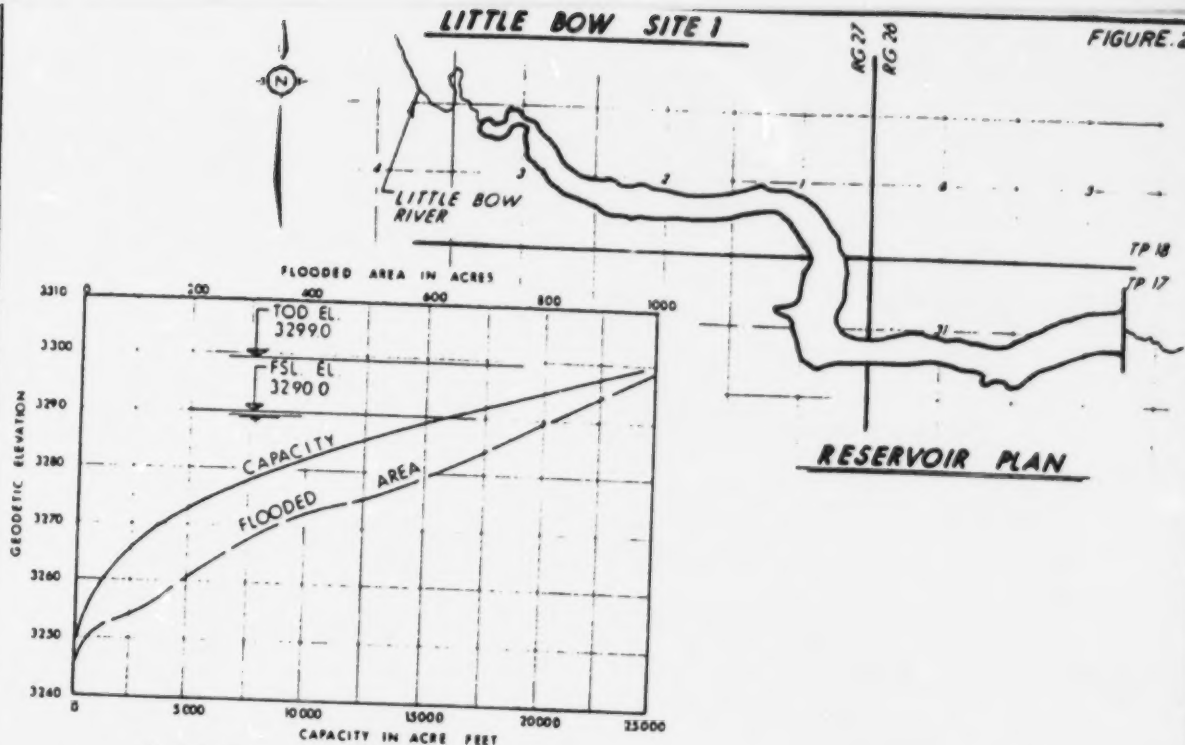
Number and Dimensions of Conduits	1 @ 6 ft. dia.
Gates	5 ft. x 5 ft.
Intake Elevation	3,245 ft.
Design Capacity	300 cfs
Elevation to Pass Design Capacity	3,255 ft.

COST ESTIMATE SUMMARY

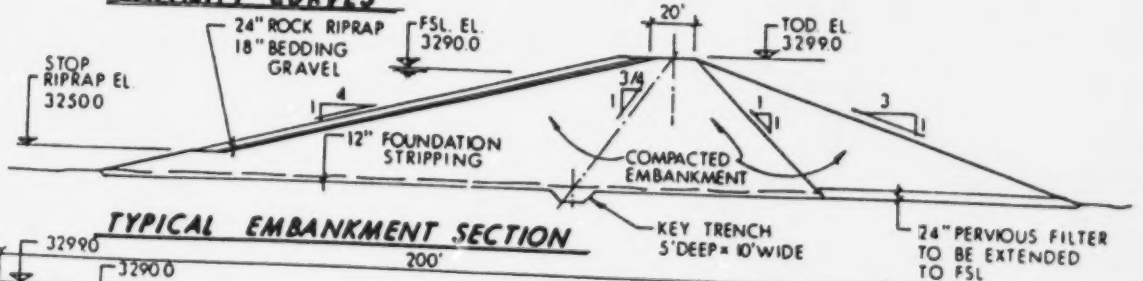
Care of Water	193,000
Embankment	2,435,000
Spillway	931,000
Diversion and Outlet Works	500,000
Subtotal	4,059,000
Contingencies (25%)	1,015,000
Subtotal	5,074,000
Engineering (15%)	761,000
Reservoir Costs	1,436,000
TOTAL PROJECT COST	\$7,271,000

LITTLE BOW SITE 1

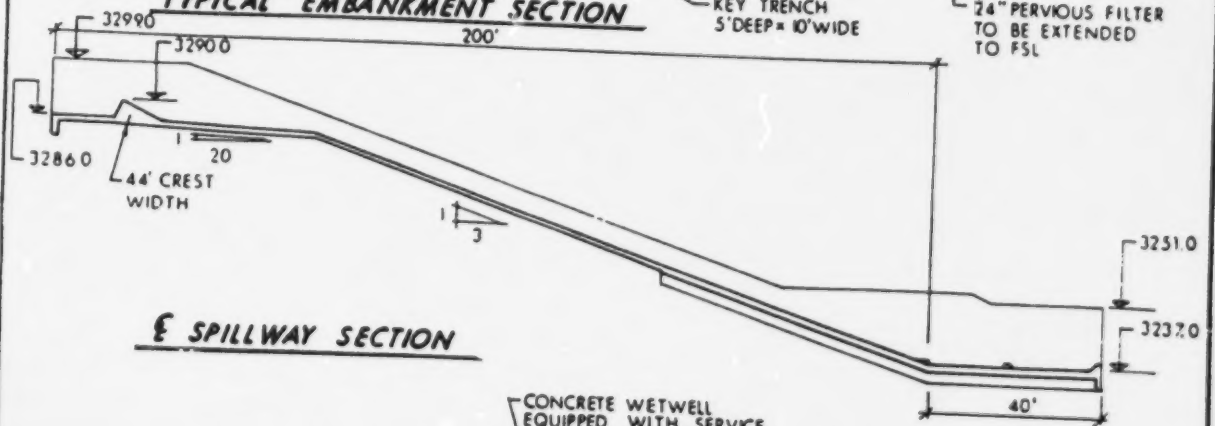
FIGURE 2.



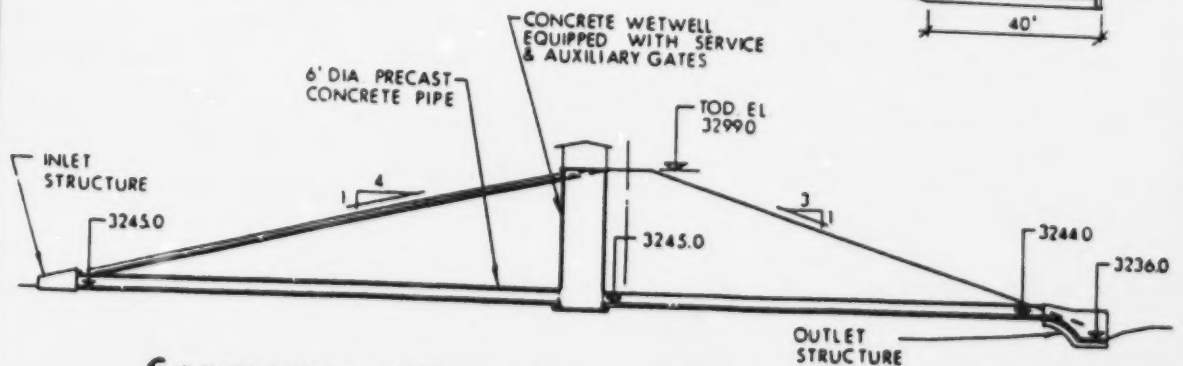
FLOODED AREA AND CAPACITY CURVES



TYPICAL EMBANKMENT SECTION



SPILLWAY SECTION



DIVERSION & OUTLET WORKS SECTION

TABLE 2
LITTLE BOW SITE 2

PROJECT DATA

Reservoir

Effective Drainage Area	81 mi ²
Full Supply Level (FSL)	3,249 ft.
Total Storage at FSL	27,500 ac.ft.
Live Storage	27,100 ac.ft.
Flooded Area at FSL	1,725 ac.
Safety-of-Dam Flood (0.5 probable maximum mean daily inflow)	8,362 cfs

Embankment

Top of Dam Elevation	3,261 ft.
Maximum Height	51 ft.
Volume of Fill	484,140 yds. ³

Spillway

Type of Spillway	Concrete Chute
Crest Elevation	3,249 ft.
Spillway Design Discharge	3,550 cfs
- (estimated 1:100 routed outflow)	
Safety-of-Dam Discharge	8,362 cfs
- (0.5 probable maximum mean daily inflow)	

Diversion and Outlet Works

Number and Dimensions of Conduits	1 @ 6 ft. dia.
Gates	5 ft. x 5 ft.
Intake Elevation	3,215 ft.
Design Capacity	300 cfs
Elevation to Pass Design Capacity	3,225 ft.

COST ESTIMATE SUMMARY

Care of Water	181,000
Embankment	2,454,000
Spillway	737,000
Diversion and Outlet Works	436,000
Subtotal	3,808,000
Contingencies (25%)	952,000
Subtotal	4,760,000
Engineering (15%)	714,000
Reservoir Costs	3,166,000
TOTAL PROJECT COST	\$8,640,000

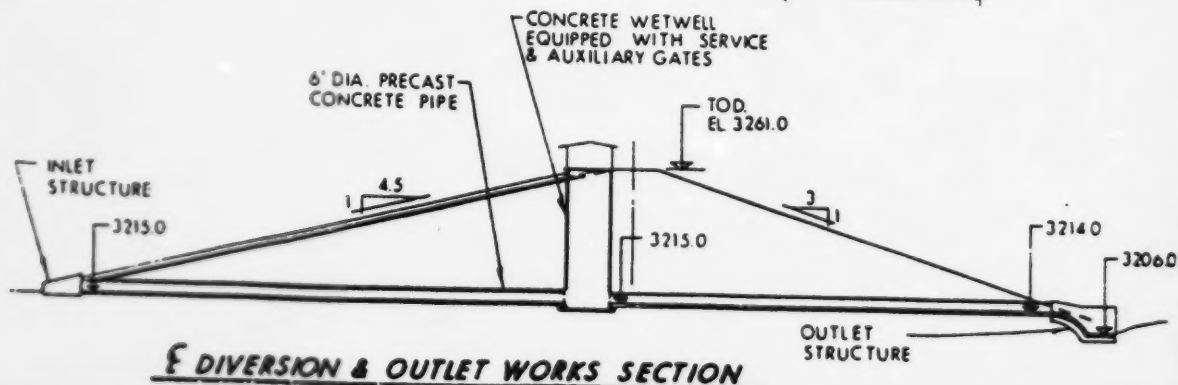
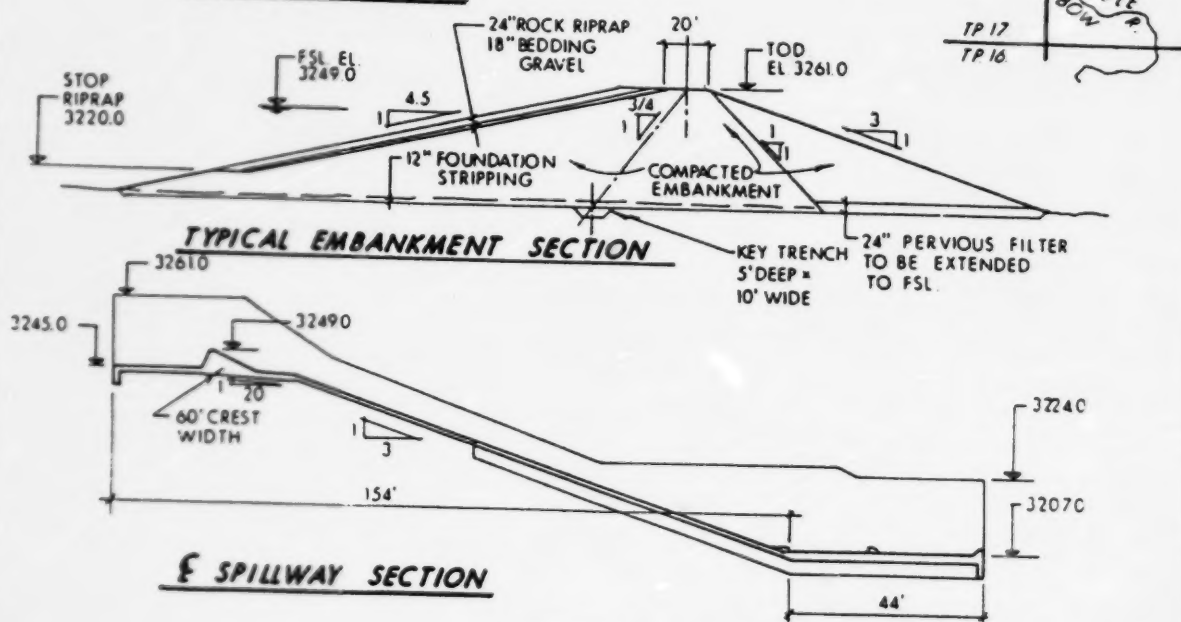
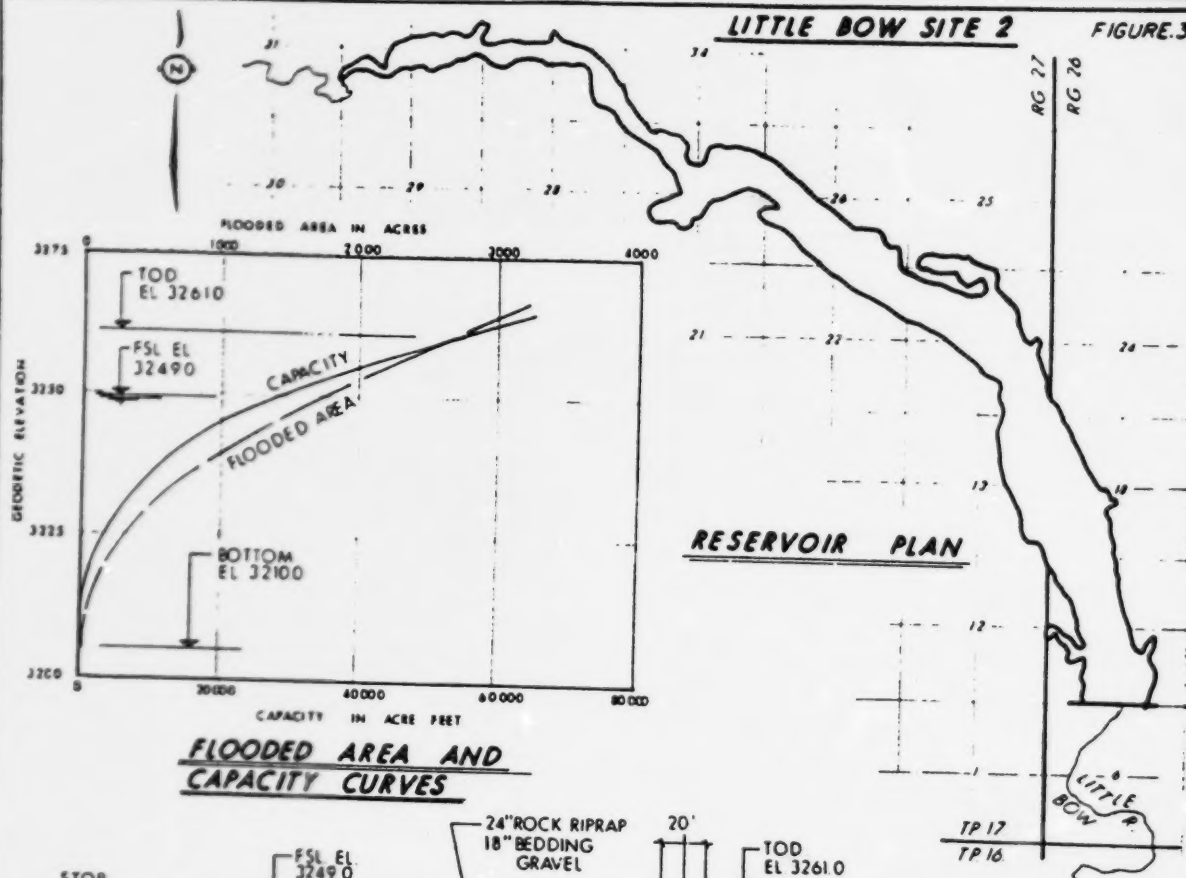


TABLE 3
LITTLE BOW SITE 3

PROJECT DATA

Reservoir

Effective Drainage Area	116 mi ²
Full Supply Level (FSL)	3,225 ft.
Total Storage at FSL	27,500 ac.ft.
Live Storage	26,500 ac.ft.
Flooded Area at FSL	1,570 ac.
Safety-of-Dam Flood (0.5 probable maximum mean daily inflow)	9,030 cfs

Embankment

Top of Dam Elevation	3,238 ft.
Maximum Height	48 ft.
Volume of Fill	544,890 yds. ³

Spillway

Type of Spillway	Concrete Chute
Crest Elevation	3,225 ft.
Spillway Design Discharge	4,445 cfs
- (estimated 1:100 routed outflow)	
Safety-of-Dam Discharge	9,030 cfs
- (0.5 probable maximum mean daily inflow)	

Diversion and Outlet Works

Number and Dimensions of Conduits	1 @ 6 ft. dia.
Gates	5 ft. x 5 ft.
Intake Elevation	3,195 ft.
Design Capacity	300 cfs
Elevation to Pass Design Capacity	3,205 ft.

COST ESTIMATE SUMMARY

Care of Water	180,000
Embankment	2,374,000
Spillway	838,000
Diversion and Outlet Works	390,000
Subtotal	3,782,000
Contingencies (25%)	946,000
Subtotal	4,728,000
Engineering (15%)	709,000
Reservoir Costs	3,505,000
TOTAL PROJECT COST	\$8,942,000

LITTLE BOW SITE 3

FIGURE 4.

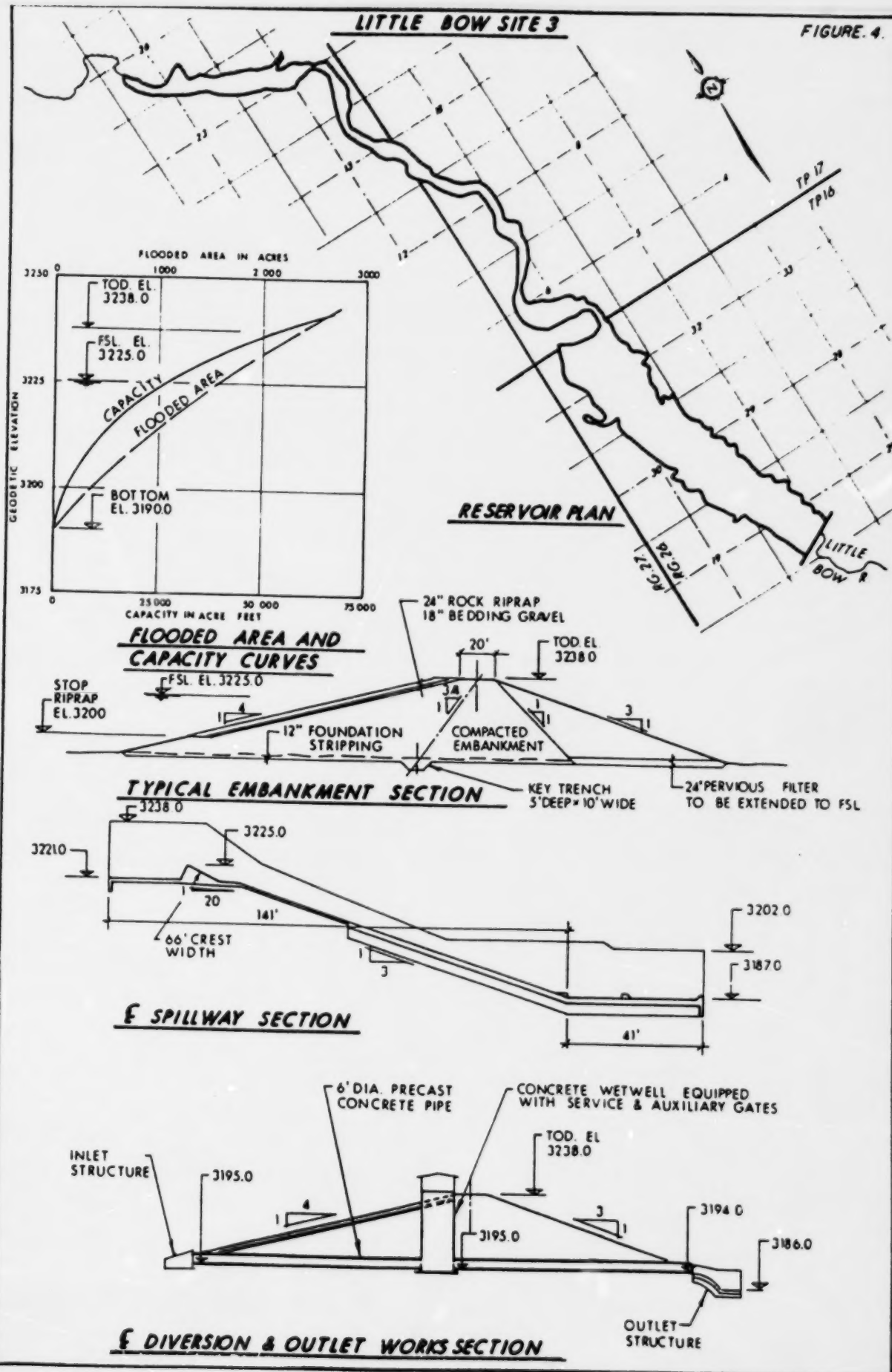


TABLE 4
LITTLE BOW SITE 7A

PROJECT DATA

Reservoir

Effective Drainage Area	488 mi ²
Full Supply Level (FSL)	3,145 ft.
Total Storage at FSL	41,000 ac.ft.
Live Storage	40,200 ac.ft.
Flooded Area at FSL	2,000 ac.
Safety-of-Dam Flood (0.5 probable maximum mean daily inflow)	9,500 cfs

Embankment

Top of Dam Elevation	3,156 ft.
Maximum Height	61 ft.
Volume of Fill	423,200 yds. ³

Spillway

Type of Spillway	Concrete Chute
Crest Elevation	3,145 ft.
Spillway Design Discharge	6,600 cfs
- (estimated 1:100 routed outflow)	
Safety-of-Dam Discharge	9,500 cfs
- (0.5 probable maximum mean daily inflow)	

Diversion and Outlet Works

Number and Dimensions of Conduits	1 @ 6 ft. dia.
Gates	5 ft. x 5 ft.
Intake Elevation	3,100 ft.
Design Capacity	300 cfs
Elevation to Pass Design Capacity	3,110 ft.

COST ESTIMATE SUMMARY

Care of Water	170,000
Embankment	1,842,000
Spillway	1,049,000
Diversion and Outlet Works	512,000
Subtotal	3,573,000
Contingencies (25%)	893,000
Subtotal	4,466,000
Engineering (15%)	670,000
Reservoir Costs	3,900,000
TOTAL PROJECT COST	\$9,036,000

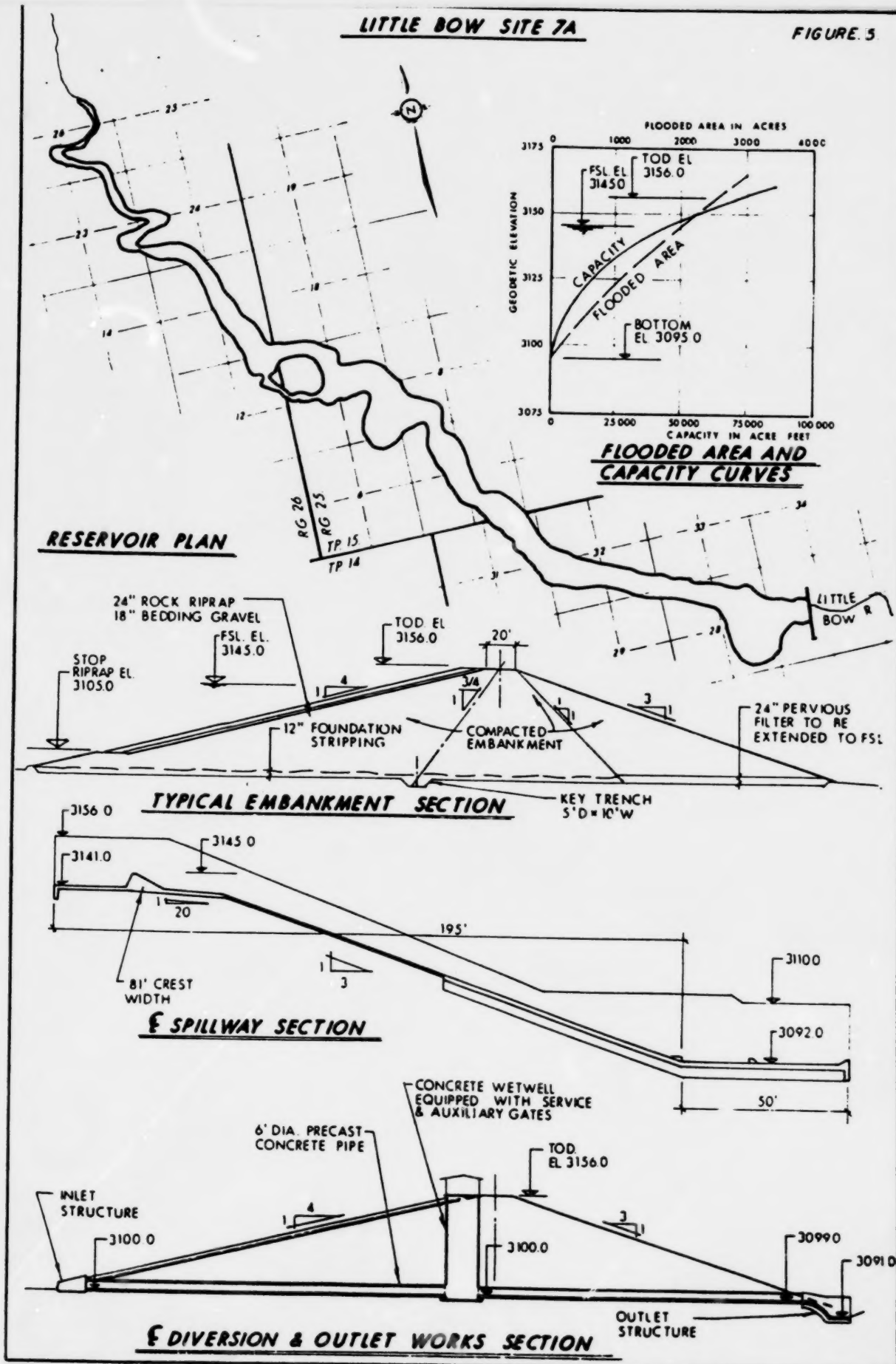


TABLE 5
MOSQUITO CREEK SITE 3

PROJECT DATA

Reservoir

Effective Drainage Area	158 mi ²
Full Supply Level (FSL)	3,425 ft.
Total Storage at FSL	5,920 ac.ft.
Live Storage	5,880 ac.ft.
Flooded Area at FSL	465 ac.
Safety-of-Dam Flood (0.5 probable maximum mean daily inflow)	7,505 cfs

Embankment

Top of Dam Elevation	3,435 ft.
Maximum Height	40 ft.
Volume of Fill	404,540 yds. ³

Spillway

Type of Spillway	Concrete Chute
Crest Elevation	3,425 ft.
Spillway Design Discharge	5,370 cfs
- (estimated 1:100 routed outflow)	
Safety-of-Dam Discharge	7,505 cfs
- (0.5 probable maximum mean daily inflow)	

Diversion and Outlet Works

Number and Dimensions of Conduits	1 @ 6 ft. dia.
Gates	5 ft. x 5 ft.
Intake Elevation	3,400 ft.
Design Capacity	300 cfs
Elevation to Pass Design Capacity	3,410 ft.

COST ESTIMATE SUMMARY

Care of Water	152,000
Embankment	1,973,000
Spillway	686,000
Diversion and Outlet Works	389,000
Subtotal	3,200,000
Contingencies (25%)	800,000
Subtotal	4,000,000
Engineering (15%)	600,000
Reservoir Costs	1,229,000
TOTAL PROJECT COST	\$5,829,000

MOSQUITO CREEK SITE 3

FIGURE 6.

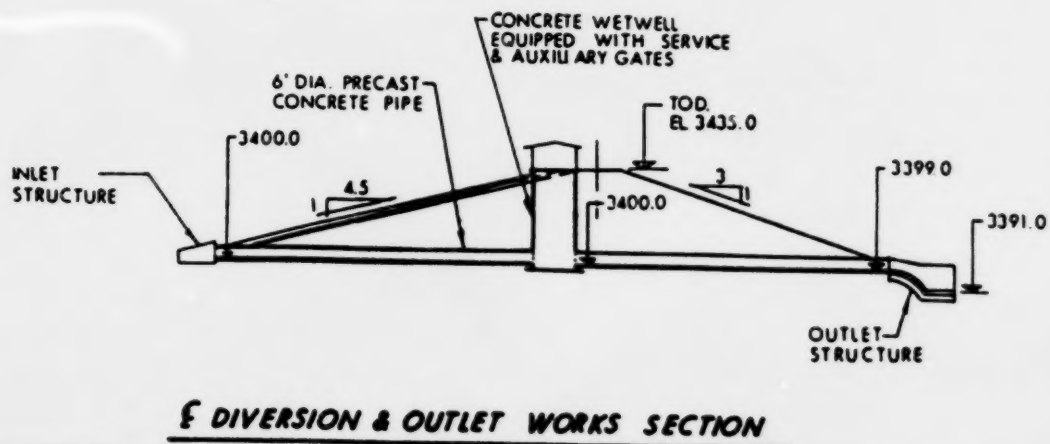
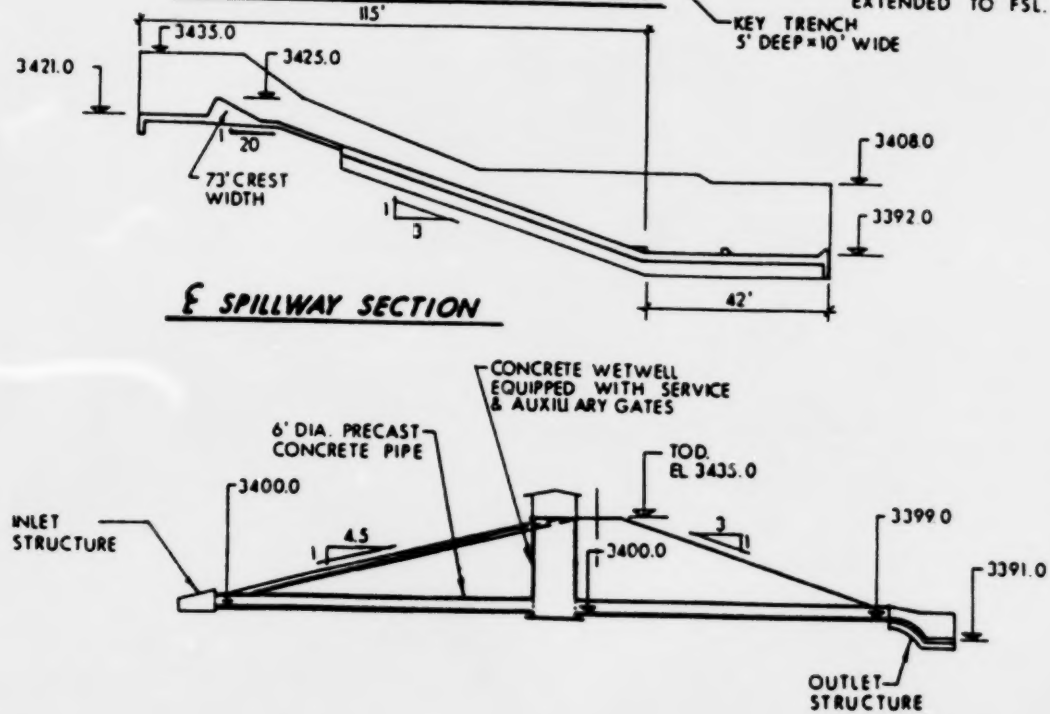
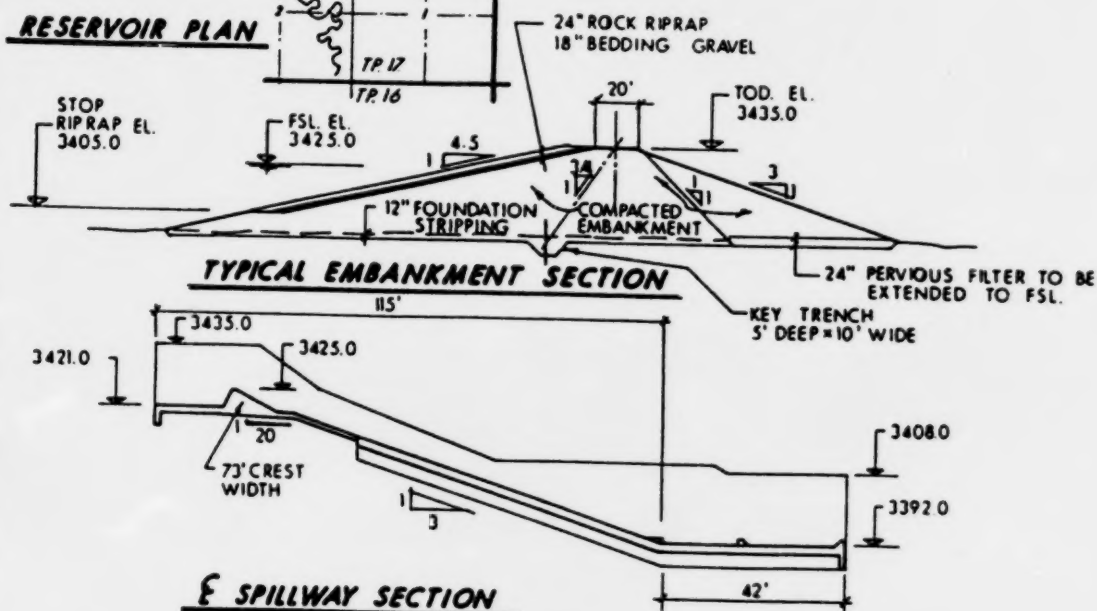
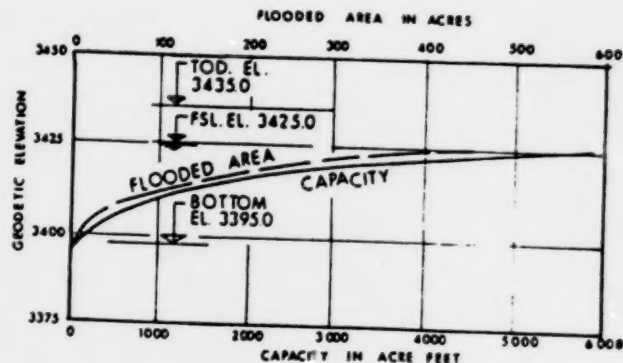
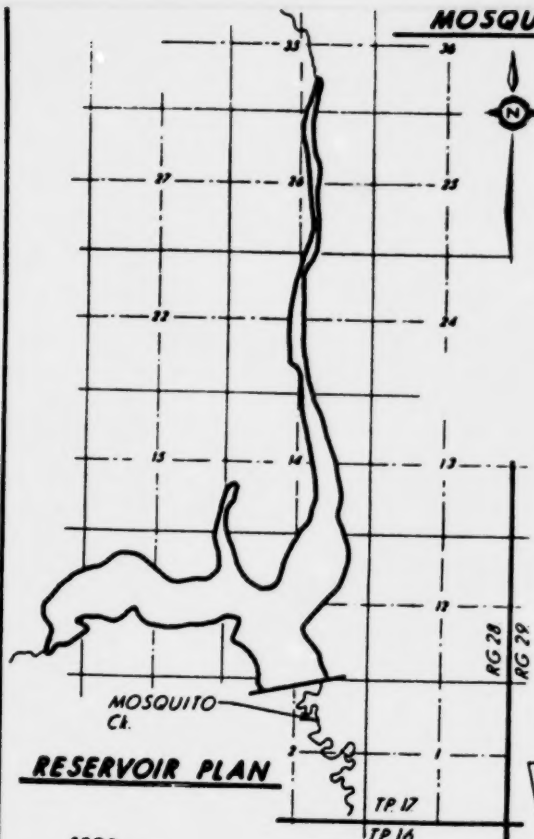


TABLE 6
MOSQUITO CREEK SITE 4

PROJECT DATA

Reservoir

Effective Drainage Area	175 mi ²
Full Supply Level (FSL)	3,423 ft.
Total Storage at FSL	21,000 ac.ft.
Live Storage	20,080 ac.ft.
Flooded Area at FSL	1,200 ac.
Safety-of-Dam Flood (0.5 probable maximum mean daily inflow)	7,875 cfs

Embankment

Top of Dam Elevation	3,433 ft.
Maximum Height	65 ft.
Volume of Fill	362,000 yds. ³

Spillway

Type of Spillway	Concrete Chute
Crest Elevation	3,423 ft.
Spillway Design Discharge	5,715 cfs
- (estimated 1:100 routed outflow)	
Safety-of-Dam Discharge	7,875 cfs
- (0.5 probable maximum mean daily inflow)	

Diversion and Outlet Works

Number and Dimensions of Conduits	1 @ 6 ft. dia.
Gates	5 ft. x 5 ft.
Intake Elevation	3,378 ft.
Design Capacity	300 cfs
Elevation to Pass Design Capacity	3,388 ft.

COST ESTIMATE SUMMARY

Care of Water	155,000
Embankment	1,493,000
Spillway	1,113,000
Diversion and Outlet Works	500,000
Subtotal	3,261,000
Contingencies (25%)	815,000
Subtotal	4,076,000
Engineering (15%)	611,000
Reservoir Costs	1,847,000
TOTAL PROJECT COST	6,534,000

MOSQUITO CREEK SITE 4

FIGURE 7.

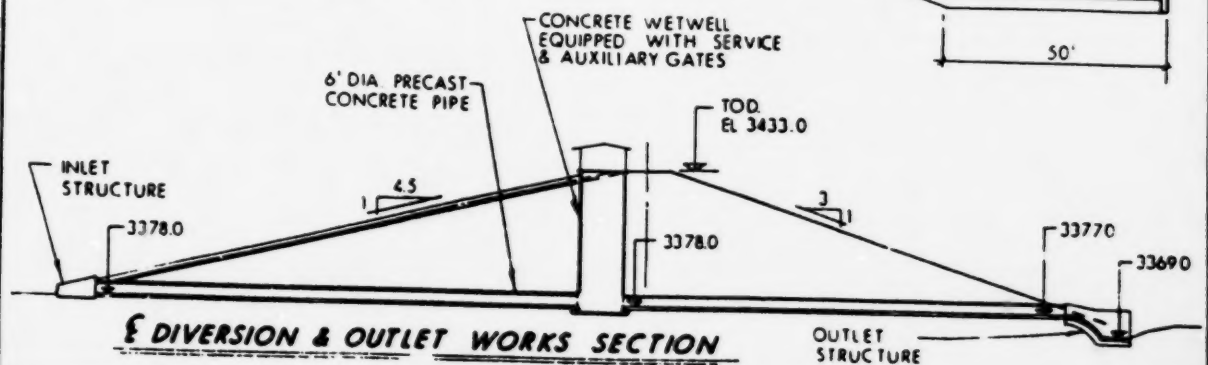
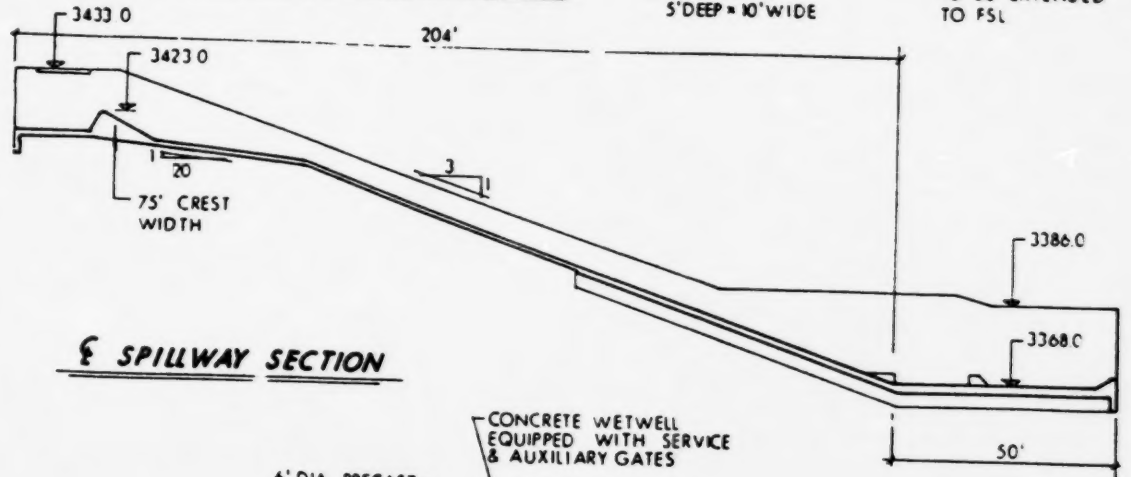
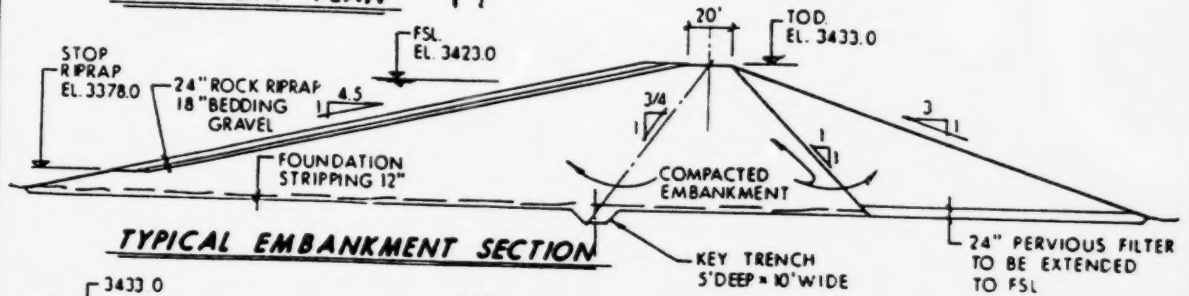
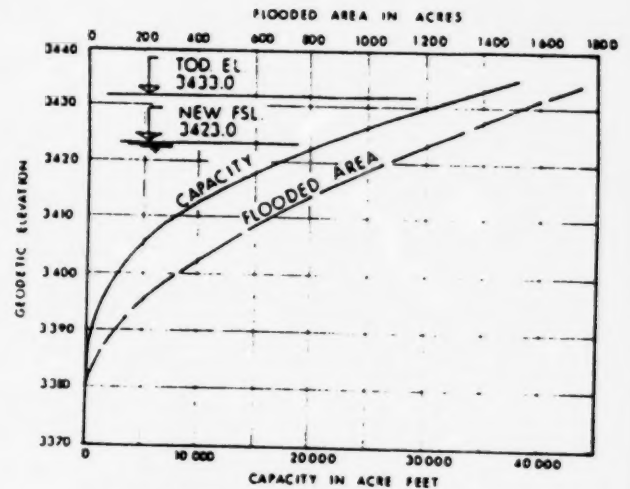
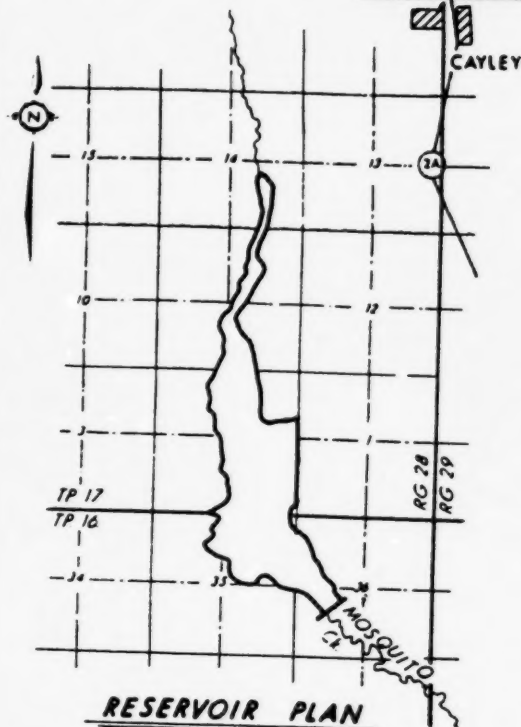


TABLE 7
SOJAW COULÉE 1110 2

PROJECT DATA

Reservoir

Effective Drainage Area	20 mi ²
Full Supply Level (FSL)	3,500 ft.
Total Storage at FSL	14,400 ac.ft.
Live Storage	14,300 ac.ft.
Flooded Area at FSL	600 ac.
Safety-of-Dam Flood (0.5 probable maximum mean daily inflow)	2,800 cfs

Embankment

Top of Dam Elevation	3,509 ft.
Maximum Height	69 ft.
Volume of Fill	240,210 yds. ³

Spillway

Type of Spillway	Concrete Chute
Crest Elevation	3,500 ft.
Spillway Design Discharge	1,490 cfs
- (estimated 1:100 routed outflow)	
Safety-of-Dam Discharge	2,800 cfs
- (0.5 probable maximum mean daily inflow)	

Diversion and Outlet Works

Number and Dimensions of Conduits	1 @ 6 ft. dia.
Gates	5 ft. x 5 ft.
Intake Elevation	3,445 ft.
Design Capacity	300 cfs
Elevation to Pass Design Capacity	3,455 ft.

COST ESTIMATE SUMMARY

Care of Water	112,000
Embankment	1,069,000
Spillway	630,000
Diversion and Outlet Works	542,000
Subtotal	2,353,000
Contingencies (25%)	588,000
Subtotal	2,941,000
Engineering (15%)	441,000
Reservoir Costs	1,209,000
TOTAL PROJECT COST	4,591,000

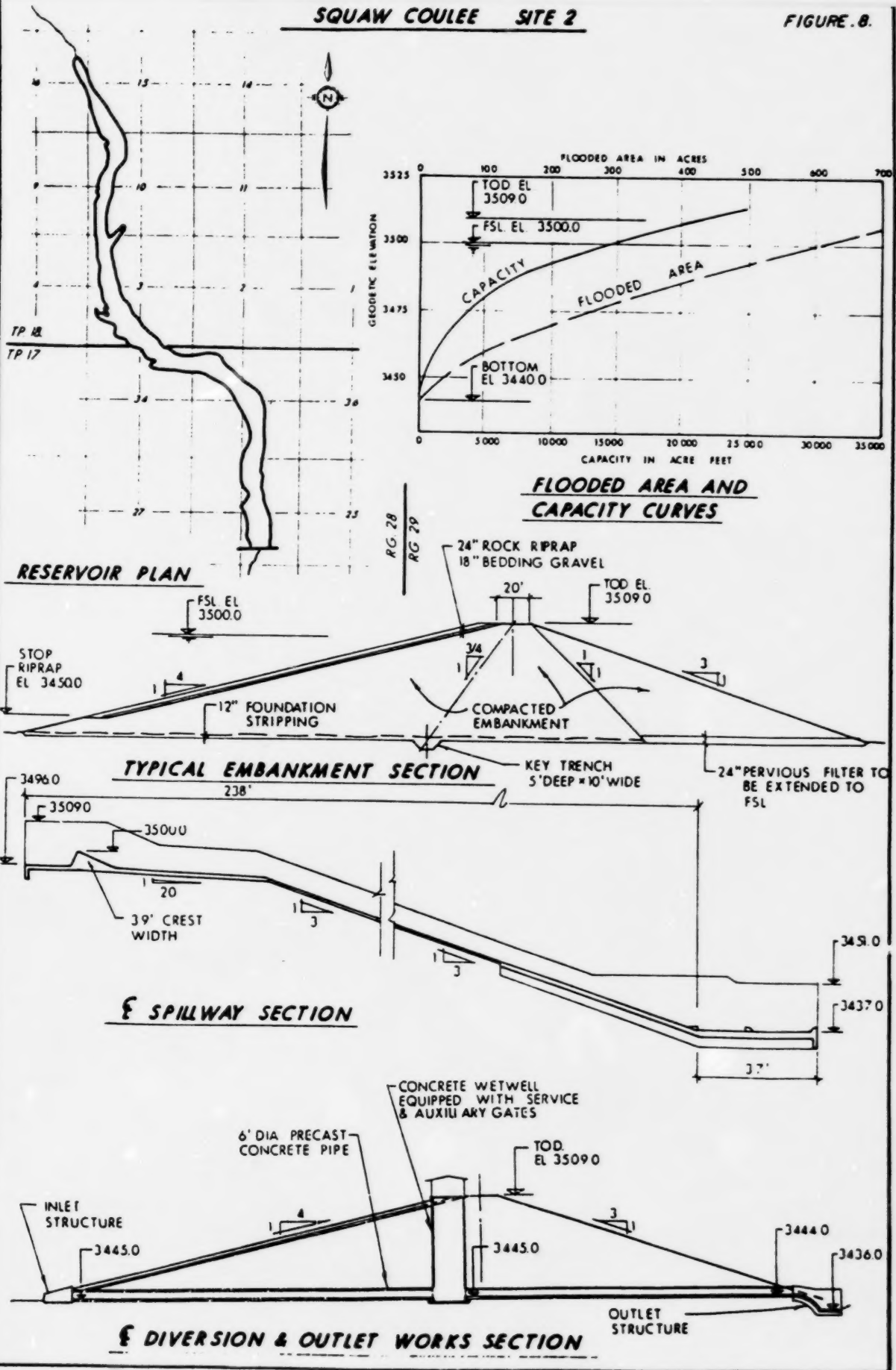


TABLE 8
SQUAW COULEE SITE 2A

PROJECT DATA

Reservoir

Effective Drainage Area	22 mi ²
Full Supply Level (FSL)	3,500 ft.
Total Storage at FSL	21,000 ac.ft.
Live Storage	20,950 ac.ft.
Flooded Area at FSL	790 ac.
Safety-of-Dam Flood (0.5 probable maximum mean daily flow)	2,970 cfs

Embankment

Top of Dam Elevation	3,509 ft.
Maximum Height	94 ft.
Volume of Fill	704,230 yds. ³

Spillway

Type of Spillway	Concrete Chute
Crest Elevation	3,500 ft.
Spillway Design Discharge	1,595 cfs
- (estimated 1:100 routed outflow)	
Safety-of-Dam Discharge	2,970 cfs
- (0.5 probable maximum mean daily inflow)	

Diversion and Outlet Works

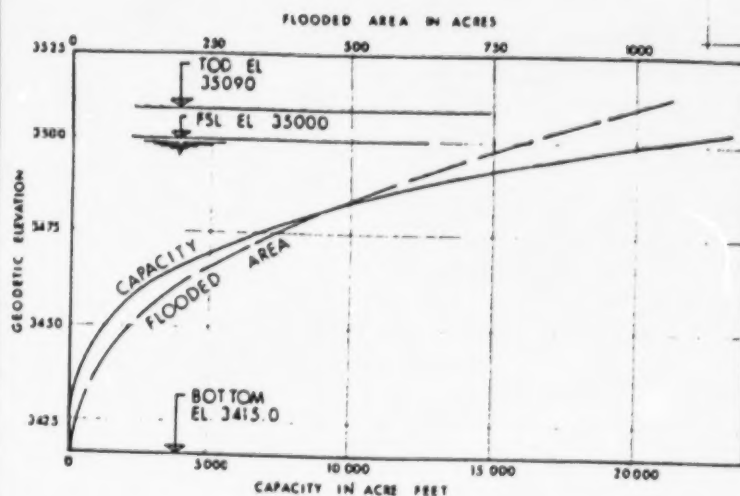
Number and Dimensions of Conduits	1 @ 6 ft. dia.
Gates	5 ft. x 5 ft.
Intake Elevation	3,420 ft.
Design Capacity	300 cfs
Elevation to Pass Design Capacity	3,430 ft.

COST ESTIMATE SUMMARY

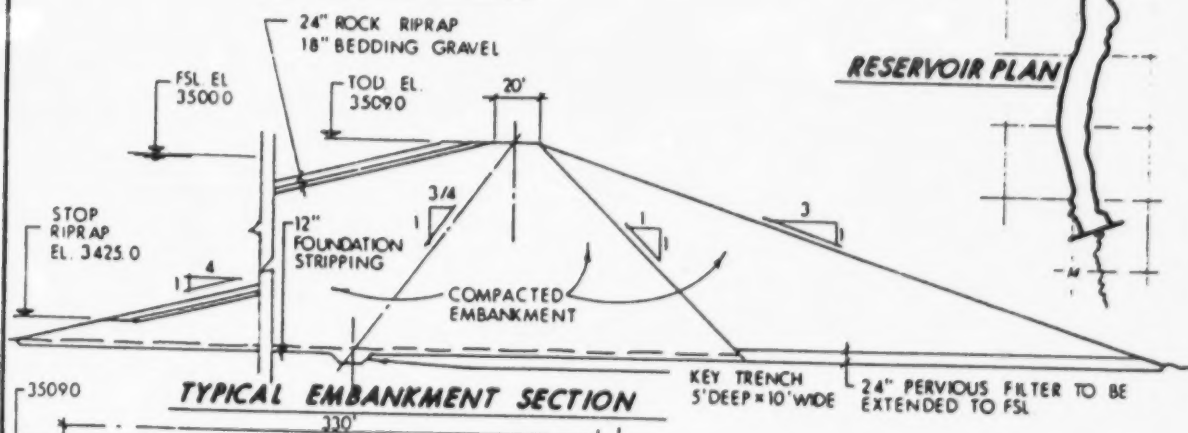
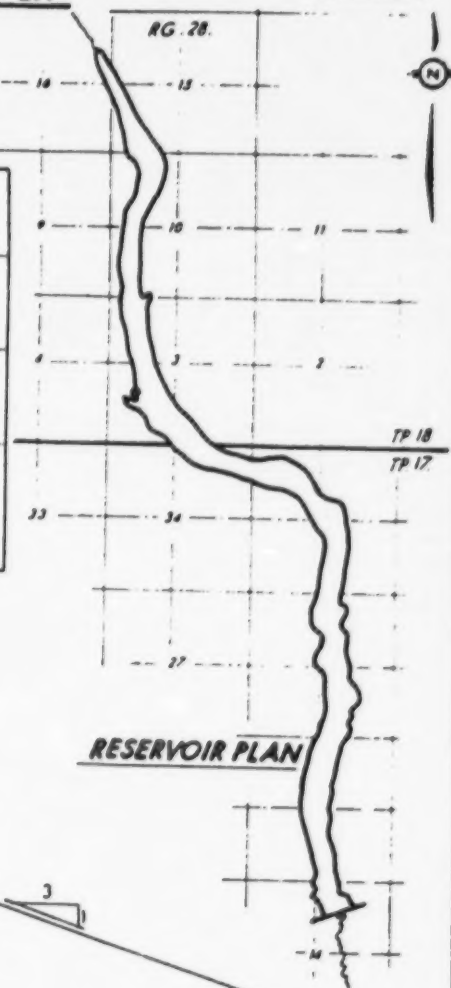
Care of Water	232,000
Embankment	2,785,000
Spillway	1,156,000
Diversion and Outlet Works	700,000
Subtotal	4,873,000
Contingencies (25%)	1,218,000
Subtotal	6,091,000
Engineering (15%)	914,000
Reservoir Costs	1,681,000
TOTAL PROJECT COST	\$8,686,000

SQUAW COULEE SITE 2A

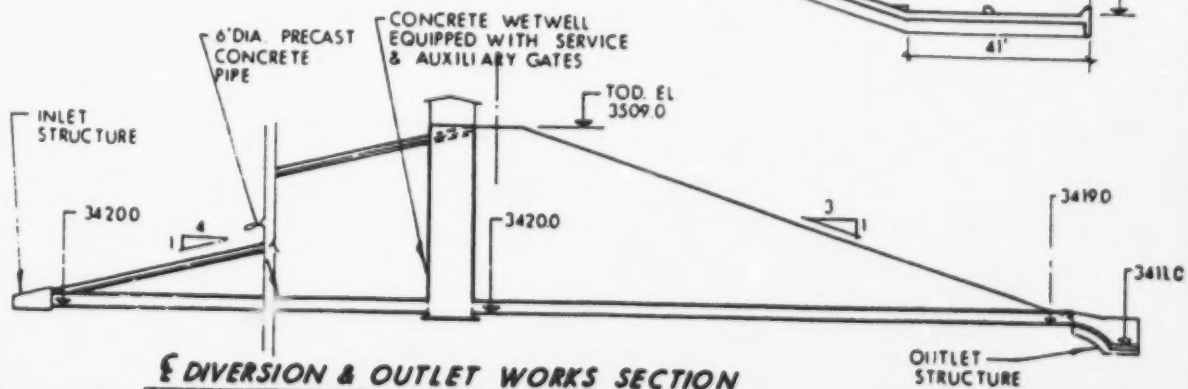
FIGURE 9.



FLOODED AREA AND CAPACITY CURVES



SPILLWAY SECTION



RESERVOIR	DAM HEIGHT (FT.)	FLOODED AREA AT FSL. (AC)	STORAGE (AC.FT.)	AVAILABLE FOR USE IN BASIN (AC.FT.)	GEOTECHNICAL OVERVIEW	RESERVOIR DAMAGES		TOTAL PROJECT COST (\$)
						LAND AND BLDGS.	ROADS AND UTILITIES	
LITTLE BOW 1	59	810	17,250	35,800	-GOOD FOUNDATION -POTENTIAL SEEPAGE THROUGH VALLEY BOTTOM ALLUVIUM -CONSTRUCTION MATERIALS AVAILABLE	-700 AC. CULTIVATION -300 AC. GRASSLAND -3 FARMSTEADS FLOODED	-1 EXISTING ROAD AND BRIDGE TO BE RAISED	7,271,000
LITTLE BOW 2	51	1,725	27,500	38,600	-LOCATED ON BURIED VALLEY -SEEPAGE AND WATERTIGHTNESS ARE OF CONCERN -CONSTRUCTION MATERIALS AVAILABLE	-1250 AC. CULTIVATION -1550 AC. GRASSLAND -5 FARMSTEADS FLOODED	-2 ROADS TO BE DYKED -1 ROAD AND BRIDGE TO BE RAISED -2 ROADS TO BE ABANDONED -1 POWERLINE TO BE UPGRADED	8,640,000
LITTLE BOW 3	48	1,570	27,500	38,600	-GOOD FOUNDATION -POTENTIAL SEEPAGE THROUGH VALLEY BOTTOM AND ABUTMENTS -CONSTRUCTION MATERIALS AVAILABLE	-1300 AC. CULTIVATION -1000 AC. GRASSLAND -3 FARMSTEADS FLOODED	-3 ROADS AND BRIDGES TO BE RAISED -1 ROAD TO BE ABANDONED -1 POWERLINE TO BE UPGRADED	8,942,000
LITTLE BOW 7A	61	2,000	41,000	42,000	-GOOD FOUNDATION -SEEPAGE THROUGH VALLEY BOTTOM IS OF CONCERN -CONSTRUCTION MATERIALS AVAILABLE	-1300 AC. CULTIVATION -1200 AC. GRASSLAND -6 FARMSTEADS FLOODED	-2 ROADS AND BRIDGES TO BE RAISED -1 ROAD TO BE ABANDONED	9,036,000
MOSQUITO CREEK 3	40	465	5,920	19,600	-LOCATED ON BURIED VALLEY -SEEPAGE CONTROL A PROBLEM -POTENTIAL SETTLEMENT PROBLEM -CONSTRUCTION MATERIALS AVAILABLE	-100 AC. CULTIVATION -675 AC. GRASSLAND -1 FARMSTEAD FLOODED	-1 ROAD AND BRIDGE TO BE RAISED -1 NEW FARM ACCESS ROAD	5,829,000
MOSQUITO CREEK 4	65	1,200	21,000	38,400	-BURIED VALLEY UNDER UPPER PART OF RESERVOIR -SEEPAGE LOSSES OF CONCERN -POSSIBLE SETTLEMENT PROBLEM -CONSTRUCTION MATERIALS FROM OUTSIDE OF RESERVOIR	-625 AC. CULTIVATION -717 AC. GRASSLAND	-2 ROADS TO BE RAISED -PUMPING REQUIRED FOR SURFACE DRAINAGE	6,534,000
SQUAW COULEE 2	69	600	14,400	34,400	-GOOD FOUNDATION -SEEPAGE THROUGH VALLEY BOTTOM AND ABUTMENTS -REQUIRE CONSTRUCTION MATERIALS FROM OUTSIDE OF RESERVOIR	-30 AC. CULTIVATION -690 AC. GRASSLAND -NO BUILDINGS	-1 ROAD AND BRIDGE TO BE RAISED	4,591,000
SQUAW COULEE 2A	94	790	21,000	39,400	-GOOD FOUNDATION -SEEPAGE THROUGH VALLEY BOTTOM AND ABUTMENTS -REQUIRE CONSTRUCTION MATERIALS FROM OUTSIDE OF RESERVOIR	-30 AC. CULTIVATION -870 AC. GRASSLAND	-2 ROADS AND BRIDGES TO BE RAISED	8,686,000

RESERVOIR DAMAGES		TOTAL PROJECT COST (\$)	COST (\$/AC.FT.)		REMARKS	RECOMMENDATIONS
LAND AND BLDGS.	ROADS AND UTILITIES		STORAGE	AVAILABLE WATER SUPPLY		
-700 AC. CULTIVATION -300 AC. GRASSLAND -3 FARMSTEADS FLOODED	-1 EXISTING ROAD AND BRIDGE TO BE RAISED	7,271,000	422	203	-SUPPLIED MAINLY BY LITTLE BOW DIVERSION -SUPPLIES REACH 1 AND MOST OF REACH 2 -MOST ECONOMICAL LITTLE BOW SITE IN TERMS OF FIRM DRAFT	-RETAIN FOR FURTHER STUDIES NEXT STAGE
-1250 AC. CULTIVATION -1550 AC. GRASSLAND -5 FARMSTEADS FLOODED	-2 ROADS TO BE DYKED -1 ROAD AND BRIDGE TO BE RAISED -2 ROADS TO BE ABANDONED -1 POWERLINE TO BE UPGRADED	8,640,000	314	224	-SUPPLIED MAINLY BY LITTLE BOW DIVERSION -SUPPLIES REACH 1 AND HALF OF REACH 2	-DELETE
-1300 AC. CULTIVATION -1000 AC. GRASSLAND -3 FARMSTEADS FLOODED	-3 ROADS AND BRIDGES TO BE RAISED -1 ROAD TO BE ABANDONED -1 POWERLINE TO BE UPGRADED	8,942,000	325	232	-SUPPLIED MAINLY BY LITTLE BOW DIVERSION -SUPPLIES REACH 1 AND 1/3 OF REACH 2	-DELETE FROM CURRENT STUDY, CONSIDER IF HIGHWOOD DIVERSION INCREASED
-1300 AC. CULTIVATION -1200 AC. GRASSLAND -6 FARMSTEADS FLOODED	-2 ROADS AND BRIDGES TO BE RAISED -1 ROAD TO BE ABANDONED	9,036,000	220	215	-SUPPLIED BY BOTH DIVERSIONS AND MOSQUITO CREEK -SUPPLIES REACH 1 ONLY -COULD SUPPLY CLEAR LAKE WITH PUMPING -MOST ECONOMICAL SITE IN TERMS OF RESERVOIR STORAGE	-RETAIN FOR FURTHER STUDY CONFLUENCE INVESTIGATION
-100 AC. CULTIVATION -675 AC. GRASSLAND -1 FARMSTEAD FLOODED	-1 ROAD AND BRIDGE TO BE RAISED -1 NEW FARM ACCESS ROAD	5,829,000	985	297	-SUPPLIED BY SQUAW COULEE DIVERSION PLUS MOSQUITO CREEK -SUPPLIES REACH 1 AND PART OF REACH 3 -WOULD SUPPLY CLEAR LAKE BY GRAVITY DIVERSION	-DELETE
-625 AC. CULTIVATION -717 AC. GRASSLAND	-2 ROADS TO BE RAISED -PUMPING REQUIRED FOR SURFACE DRAINAGE	6,534,000	311	170	-SUPPLIED BY SQUAW COULEE DIVERSION PLUS MOSQUITO CREEK -SUPPLIES REACH 1 AND PART OF REACH 3 -COULD SUPPLY CLEAR LAKE BY GRAVITY DIVERSION	-RETAIN FOR FURTHER STUDY NEXT STAGE
-30 AC. CULTIVATION -690 AC. GRASSLAND -NO BUILDINGS	-1 ROAD AND BRIDGE TO BE RAISED	4,591,000	319	133	-SUPPLIED BY SQUAW COULEE DIVERSION -SUPPLIES REACH 1 AND REACH 3 -COULD SUPPLY CLEAR LAKE BY GRAVITY DIVERSION -MOST ECONOMICAL SITE ON BASIS OF FIRM DRAFT	-RETAIN FOR FURTHER STUDY NEXT STAGE
-30 AC. CULTIVATION -870 AC. GRASSLAND	-2 ROADS AND BRIDGES TO BE RAISED	8,686,000	414	220	-SUPPLIED BY SQUAW COULEE DIVERSION -SUPPLIES REACH 1 AND REACH 3 -COULD SUPPLY CLEAR LAKE BY GRAVITY DIVERSION -MORE EXPENSIVE THAN SQUAW COULEE 2	-DELETE

SCREENING TABLE
TABLE.9

LIST OF APPENDICES

- A - WATER SUPPLY AND HYDROLOGY
(Nanuk Engineering and Development Ltd.)
- B - PRELIMINARY GEOLOGICAL AND GEOTECHNICAL ASSESSMENT
(Thurber Consultants Ltd.)
- C - PRELIMINARY COST ESTIMATE ANALYSIS
- D - RESERVOIR DAMAGES AND LAND ACQUISITION

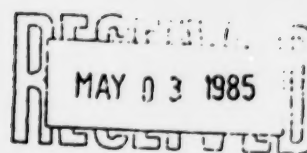
LITTLE BOW RIVER BASIN
STORAGE SITE INVESTIGATION
CONCEPTUAL DESIGN REPORT
May, 1985

APPENDIX A

WATER SUPPLY AND HYDROLOGY



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Cochrane, Alberta T0L 0W0
Telephone (403) 932-3593



NANUK ENGINEERING & DEVELOPMENT LTD.

May 3, 1985

WER Engineering
Horizon 39 Building Room 306
2735 39 Avenue NE
Calgary, Alberta
T1Y 4T8

Attention: Jack Wise

RE: LITTLE BOW RIVER BASIN; STORAGE INVESTIGATION STUDY
PRELIMINARY ASSESSMENT OF WATER SUPPLY AND FLOODS

Dear Jack;

We forward, herein, a report on the preliminary assessment of water supply and floods for the comparative evaluation of storage sites in the Little Bow River Basin.

The water supply available to the storage sites was based on available diversion flows from the Highwood River calculated by Hydrocon Engineering 'Water Supply Assessment for the Little Bow River Basin'. Natural flows, evaporation and channel losses were not considered. The storage capacities at the various sites were compared on the basis of the total basin water demand that can be satisfied by the storage site. The water demand consisted, primarily, of irrigation usage.

Preliminary estimates of the probable maximum, 1 in 100 and 1 in 50 year floods were made for comparative purposes between sites and are not to be used for design purposes.

Yours truly,

M.V. Thompson, P.Eng.
Chief Engineer

MVT:lc
enclosures

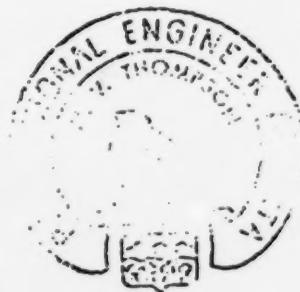
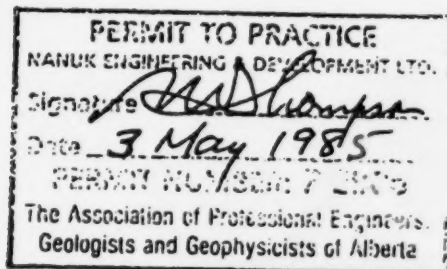


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1.0 WATER SUPPLY	A-1
2.0 FLOODS	A-4

LIST OF TABLES

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A1	Flood Flows at Storage Sites	A-5

LIST OF FIGURES

<u>Figure No.</u>		<u>Page No.</u>
A1	Yield versus Storage - Little Bow Sites 1, 2 and 3	A-3
A2	Yield versus Storage - Mosquito and Squaw Coulee Sites	A-3
A3	Yield versus Storage - Little Bow Site 7A	A-3

1.0 WATER SUPPLY

Each reservoir site was evaluated for the maximum practical volume of storage and the ratio of basin yield to storage volume at various levels of storage. The bases of these evaluations were:

1. the water available for diversion from the Highwood River was in accordance with existing guidelines (10% of Highwood flows at Squaw Coulee and 30% of Highwood flows at the Little Bow Diversion) as calculated by Hydrocon Engineering in Scenario 'E' except that the total diversion could be routed, up to the physical capacity through either Squaw Coulee or the Little Bow Canal;
2. the physical capacities of the diversions are 60 cfs at Squaw Coulee and 100 cfs in the Little Bow Canal;
3. the diversion canals were assumed to operate from April 15 to October 15 to provide water to the reservoir;
4. the municipal and riparian flow requirement of 15 cfs will be satisfied during the winter by diversion through the Little Bow Canal;
5. natural flows were not considered in Phase I for the comparative evaluation of all sites;
6. the draft from the reservoir served a variable irrigation demand and a uniform municipal, instream use and residual flow requirement;
7. the seasonal irrigation demand was distributed as follows:

May	8%
June	30%
July	38%
August	19%
September	5%

8. evaporative losses were not considered in this conceptual study;
9. all water demands were considered to be downstream of all sites except 7A
10. for site 7A, at the confluence of the Little Bow River and Mosquito Creek, 12% of the total demand was on Mosquito Creek, 20% upstream of the site on the Little Bow and the remainder downstream of the site.

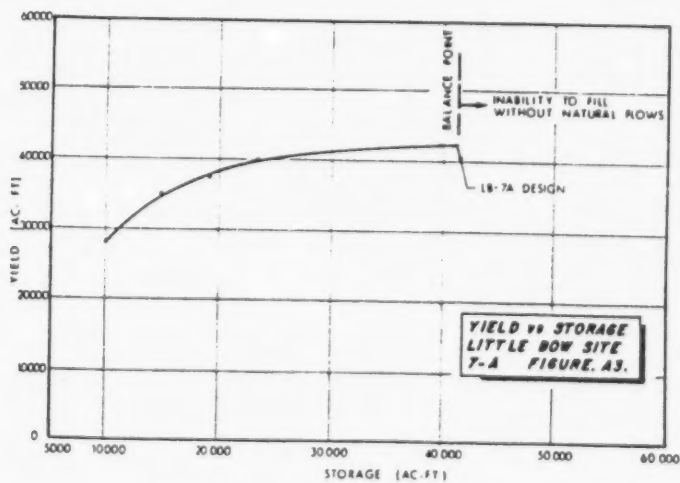
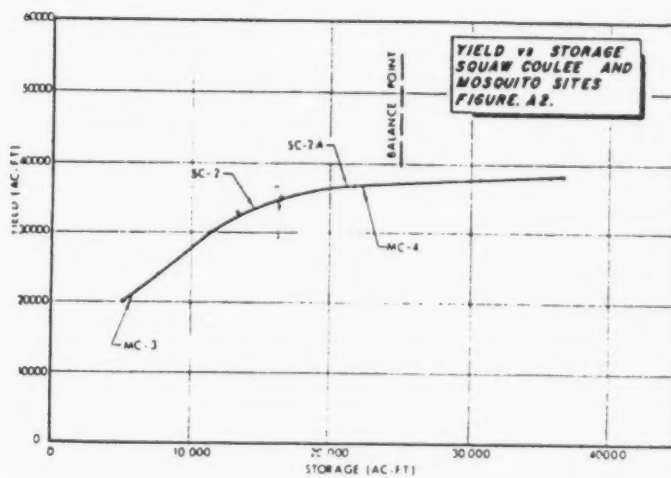
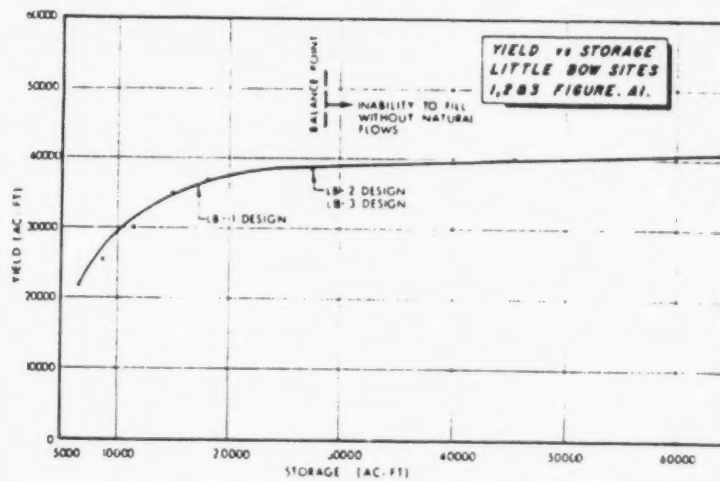
The method of evaluation used the critical period 1923 to 1938 to calculate the water balance in the reservoir. The initial part of this period was used to check that the reservoir could be filled by the fall of 1928. The latter part represents the most critical drought within the period of record. The steps used to derive the reservoir size and corresponding basin yield were:

1. set the reservoir storage capacity;
2. estimate the total basin usage of water which can be supplied by the selected storage size;
3. with the reservoir empty at the end of 1922, calculate the increase in storage over the period 1923 to 1928, using the constant annual basin usage from 2 and diversions from Scenario 'E',

4. if the reservoir cannot be filled by the end of 1928, reduce the basin usage and repeat step 3;
5. with a full reservoir, start the period 1929 to 1938 with the basin usage estimated in 2. and the diversions from Scenario 'E';
6. calculate the reservoir water balance on a monthly basis until a deficit occurs or the end of 1938 is reached;
7. if a deficit is incurred, reduce the basin usage and recalculate the water balance from 1929 to 1938;
8. if the end of 1938 is reached without deficit, and there has been no unused storage in the reservoir, the maximum yield corresponding to the reservoir's storage capacity has been reached;
9. if there has been unused storage in the reservoir, the reservoir size can be reduced by the amount of unused storage;
10. repeat the above procedure for another storage capacity until the maximum feasible storage is reached.

The diversions to the Little Bow Basin were made in the most beneficial manner within the constraints of Scenario 'E' for each reservoir. If the reservoir was on Squaw Coulee or Mosquito Creek, the diversion through Squaw Coulee was made equal to the physical diversion capacity or the total flow available for diversion, whichever was the lesser.

The maximum practical size of a reservoir was determined by determining the maximum volume available to fill a reservoir



in the period 1923 to 1928 consistent with the maximum water demand that can be satisfied in the period 1931 to 1938. This period was chosen since it contains the first and third ranked "DRY" years in terms of total diversions at the Little Bow Canal for Scenario 'E' (Hydrocon Engineering, "Water Supply Assessment for the Little Bow River Basin").

The results of the evaluation are displayed on Figures A1, A2 and A3. The maximum practical reservoir sizes based on diversion flows without evaporation are:

Little Bow Sites	27,500 ac.ft.
Squaw Coulee & Mosquito Creek Sites	21,000 ac.ft.
Site 7A	41,000 ac.ft.

The maximum annual basin usage that can be supplied are:

Little Bow Sites	38,600 ac.ft.
Squaw Coulee & Mosquito Creek Sites	36,000 ac.ft.
Site 7A	42,000 ac.ft.

These results do not represent the optimum reservoir size since a reservoir storage of 15,000 ac.ft. at any location in the basin will sustain an annual usage of 35,000 ac.ft.

2.0 FLOODS

The probable maximum (PMF), 1 in 100 year and 1 in 50 year floods were determined for each site. The PMF's were determined using the SNBB method for prairie streams. The 1:100 and 1:50 floods were estimated from frequency analysis of maximum mean daily discharges of Willow Creek at Nolan and Claresholm. The floods were transposed to the Little Bow Basin using drainage area ratios in the formula:

$$\frac{Q_{1b}}{Q_{will}} = \frac{A_{1b}}{A_{will}} \cdot n$$

Where 'n' was determined from the 10 years of overlapping records of the Mosquito Creek at Nanton and Willow Creek at Nolan. Pearson's Type III distribution was used to fit the data for maximum mean discharges on Willow Creek. The peak instantaneous flow was calculated based on the average ratio of recorded peaks to mean daily flow at Nolan and Claresholm.

Willow Creek hydrology was used for preliminary estimates of floods, notwithstanding the physiographic differences in the basin, since this study was for comparative purposes between reservoirs and the floods will be somewhat higher than the actual values when calculated in this manner.

The results of the analysis of flood hydrology are displayed on Table A1.

TABLE A1
FLOOD FLOWS AT STORAGE SITES

<u>Site</u>	<u>Drainage Area</u>	<u>Instantaneous Peak Flow</u>		<u>Probable Maximum Flood</u>
	<u>mi²</u>	<u>1 in 50 yr</u>	<u>1 in 100 yr</u>	<u>Mean Daily Flow</u>
		cfs	cfs	cfs
1. Squaw Coulee 2	20	1,850	2,480	5,600
2. Squaw Coulee 2A	22	1,980	2,660	5,900
3. Mosquito Creek 3	158	6,660	8,950	15,000
4. Mosquito Creek 4	175	7,080	9,500	15,800
5. Little Bow 1	30	2,380	3,200	7,200
6. Little Bow 2	68	4,400	5,920	11,300
7. Little Bow 3	104	5,500	7,400	18,100
8. Site 7A	488	10,100	16,700	22,800

LITTLE BOW RIVER BASIN
STORAGE SITE INVESTIGATION
CONCEPTUAL DESIGN REPORT
May, 1985

APPENDIX C

PRELIMINARY COST ESTIMATE ANALYSIS

LIST OF COST ESTIMATE TABLES

<u>Site</u>	<u>Table No.</u>
Little Bow Site 1	C1
Little Bow Site 2	C2
Little Bow Site 3	C3
Little Bow Site 7A	C4
Mosquito Creek Site 3	C5
Mosquito Creek Site 4	C6
Squaw Coulee Site 2	C7
Squaw Coulee Site 2A	C8

TABLE C1
Little Bow Site 1
Preliminary Cost Estimate

	<u>Quantity</u>	<u>Unit Price</u>	<u>Extension</u>
<u>Care of Water</u>	1 lump sum		<u>193,000</u>
SUBTOTAL			193,000
 <u>Embankment</u>			
Foundation preparation & Core Trench Excavation	23,110 yds ³	2.30	53,000
Borrow Area Excavation & Haul - Impervious	570,950 yds ³	1.50	857,000
Compacted Embankment	538,960 yds ³	0.70	377,000
Embankment Filter & Drainage System	10,560 yds ³	16.00	169,000
Rock Riprap	21,050 yds ³	27.00	568,000
Granular Blanket, Below Riprap	15,790 yds ³	12.00	190,000
Miscellaneous Items	1 lump sum		<u>221,000</u>
SUBTOTAL EMBANKMENT			2,435,000
 <u>Spillway</u>			
Excavation & Haul			
- Rock	11,440 yds ³	5.00	57,000
- Other	102,990 yds ³	2.00	206,000
Reinforced Concrete	1,400 yds ³	400.00	560,000
Drainage System	1 lump sum		23,000
Miscellaneous Items	1 lump sum		<u>85,000</u>
SUBTOTAL SPILLWAY			931,000
 <u>Diversion & Permanent Outlet Works</u>			
Excavation	2,700 yds ³	2.70	7,000
Reinforced Concrete (Structural)	241 yds ³	600.00	145,000
Precast Pipe	425 lin.ft.	380.00	162,000
Concrete Bedding	386 yds ³	210.00	81,000
Control Gates & Hoists	2 gates	30,000	60,000
Miscellaneous Items	1 lump sum		<u>45,000</u>
SUBTOTAL DIVERSION & OUTLET WORKS			<u>500,000</u>
SUBTOTAL CONSTRUCTION			4,059,000
Contingencies (25%)			<u>1,015,000</u>
TOTAL CONSTRUCTION COST			<u>\$5,074,000</u>

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TABLE C2
Little Bow Site 2
Preliminary Cost Estimate

	<u>Quantity</u>	<u>Unit Price</u>	<u>Extension</u>
<u>Care of Water</u>	1 lump sum		<u>181,000</u>
SUBTOTAL			181,000
 <u>Embankment</u>			
Foundation preparation & Core Trench Excavation	27,200 yds ³	2.30	63,000
Borrow Area Excavation & Haul - Impervious	525,300 yds ³	1.50	788,000
Compacted Embankment	429,288 yds ³	0.70	301,000
Embankment Filter & Drainage System	10,643 yds ³	16.00	170,000
Rock Riprap	25,260 yds ³	27.00	682,000
Granular Blanket, Below Riprap	18,945 yds ³	12.00	227,000
Miscellaneous Items	1 lump sum		<u>223,000</u>
SUBTOTAL EMBANKMENT			2,454,000
 <u>Spillway</u>			
Excavation & Haul			
- Rock	3,710 yds ³	5.00	18,000
- Other	14,860 yds ³	2.00	30,000
Reinforced Concrete	1,491 yds ³	400.00	596,000
Drainage System	1 lump sum		26,000
Miscellaneous Items	1 lump sum		<u>67,000</u>
SUBTOTAL SPILLWAY			737,000
 <u>Diversion & Permanent Outlet Works</u>			
Excavation	2,357 yds ³	2.70	6,000
Reinforced Concrete (Structural)	205 yds ³	600.00	123,000
Precast Pipe	363 lin.ft.	380.00	138,000
Concrete Bedding	330 yds ³	210.00	69,000
Control Gates & Hoists	2 gates	30,000	60,000
Miscellaneous Items	1 lump sum		<u>40,000</u>
SUBTOTAL DIVERSION & OUTLET WORKS			<u>436,000</u>
SUBTOTAL CONSTRUCTION			3,808,000
Contingencies (25%)			<u>952,000</u>
TOTAL CONSTRUCTION COST			<u>\$4,760,000</u>

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TABLE C3
Little Bow Site 3
Preliminary Cost Estimate

	<u>Quantity</u>	<u>Unit Price</u>	<u>Extension</u>
<u>Care of Water</u>	1 lump sum		<u>180,000</u>
SUBTOTAL			180,000
 <u>Embankment</u>			
Foundation preparation & Core Trench Excavation	25,730 yds ³	2.30	59,000
Borrow Area Excavation & Haul - Impervious	547,076 yds ³	1.50	821,000
Compacted Embankment	493,830 yds ³	0.70	346,000
Embankment Filter & Drainage System	11,090 yds ³	16.00	177,000
Rock Riprap	22,840 yds ³	27.00	617,000
Granular Blanket, Below Riprap	17,130 yds ³	12.00	205,000
Miscellaneous Items	1 lump sum		<u>149,000</u>
SUBTOTAL EMBANKMENT			2,374,000
 <u>Spillway</u>			
Excavation & Haul			
- Rock	17,890 yds ³	5.00	9,000
- Other	71,570 yds ³	2.00	143,000
Reinforced Concrete	1,458 yds ³	400.00	583,000
Drainage System	1 lump sum		27,000
Miscellaneous Items	1 lump sum		<u>76,000</u>
SUBTOTAL SPILLWAY			838,000
 <u>Diversion & Permanent Outlet Works</u>			
Excavation	2,098 yds ³	2.70	6,000
Reinforced Concrete (Structural)	179 yds ³	600.00	107,000
Precast Pipe	319 lin.ft.	380.00	121,000
Concrete Bedding	290 yds ³	210.00	61,000
Control Gates & Hoists	2 gates	30,000	60,000
Miscellaneous Items	1 lump sum		<u>35,000</u>
SUBTOTAL DIVERSION & OUTLET WORKS			<u>390,000</u>
SUBTOTAL CONSTRUCTION			3,782,000
Contingencies (25%)			<u>946,000</u>
TOTAL CONSTRUCTION COST			<u>\$4,728,000</u>

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TABLE C4
Little Bow Site 7A
Preliminary Cost Estimate

	<u>Quantity</u>	<u>Unit Price</u>	<u>Extension</u>
<u>Care of Water</u>	1 lump sum		<u>170,000</u>
SUBTOTAL			170,000
 <u>Embankment</u>			
Foundation preparation & Core Trench Excavation	21,280 yds ³	2.30	49,000
Borrow Area Excavation & Haul - Impervious	457,670 yds ³	1.50	687,000
Compacted Embankment	388,980 yds ³	0.70	272,000
Embankment Filter & Drainage System	8,370 yds ³	16.00	134,000
Rock Riprap	14,773 yds ³	27.00	399,000
Granular Blanket, Below Riprap	11,080 yds ³	12.00	133,000
Miscellaneous Items	1 lump sum		<u>168,000</u>
SUBTOTAL EMBANKMENT			1,842,000
 <u>Spillway</u>			
Excavation & Haul			
- Rock	0 yds ³	5.00	0
- Other	30,890 yds ³	2.00	62,000
Reinforced Concrete	2,121 yds ³	400.00	848,000
Drainage System	1 lump sum		44,000
Miscellaneous Items	1 lump sum		<u>95,000</u>
SUBTOTAL SPILLWAY			1,049,000
 <u>Diversion & Permanent Outlet Works</u>			
Excavation	2,840 yds ³	2.70	8,000
Reinforced Concrete (Structural)	238 yds ³	500.00	143,000
Precast Pipe	445 lin.ft.	380.00	169,000
Concrete Bedding	405 yds ³	210.00	85,000
Control Gates & Hoists	2 gates	30,000	60,000
Miscellaneous Items	1 lump sum		<u>47,000</u>
SUBTOTAL DIVERSION & OUTLET WORKS			<u>512,000</u>
SUBTOTAL CONSTRUCTION			3,573,000
Contingencies (25%)			<u>893,000</u>
TOTAL CONSTRUCTION COST			<u>\$4,466,000</u>

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TABLE C5
Mosquito Creek Site 3
Preliminary Cost Estimate

	<u>Quantity</u>	<u>Unit Price</u>	<u>Extension</u>
<u>Care of Water</u>	1 lump sum		<u>152,000</u>
SUBTOTAL			152,000

Embankment

Foundation preparation & Core Trench Excavation	23,980 yds ³	2.30	55,000
Borrow Area Excavation & Haul - Impervious	437,850 yds ³	1.50	657,000
Compacted Embankment	362,500 yds ³	0.70	254,000
Embankment Filter & Drainage System	8,012 yds ³	16.00	128,000
Rock Riprap	19,445 yds ³	27.00	525,000
Granular Blanket, Below Riprap	14,580 yds ³	12.00	175,000
Miscellaneous Items	1 lump sum		<u>179,000</u>
SUBTOTAL EMBANKMENT			1,973,000

Spillway

Excavation & Haul			
- Rock	0 yds ³	5.00	0
- Other	18,000 yds ³	2.00	36,000
Reinforced Concrete	1,408 yds ³	400.00	563,000
Drainage System	1 lump sum		25,000
Miscellaneous Items	1 lump sum		<u>62,000</u>
SUBTOTAL SPILLWAY			686,000

Diversion & Permanent Outlet Works

Excavation	1,980 yds ³	2.70	6,000
Reinforced Concrete (Structural)	195 yds ³	600.00	117,000
Precast Pipe	299 lin.ft.	380.00	114,000
Concrete Bedding	272 yds ³	210.00	57,000
Control Gates & Hoists	2 gates	30,000	60,000
Miscellaneous Items	1 lump sum		<u>35,000</u>
SUBTOTAL DIVERSION & OUTLET WORKS			<u>389,000</u>
SUBTOTAL CONSTRUCTION			3,200,000
Contingencies (25%)			<u>800,000</u>
TOTAL CONSTRUCTION COST			\$4,000,000

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TABLE C6
Mosquito Creek Site 4
Preliminary Cost Estimate

	<u>Quantity</u>	<u>Unit Price</u>	<u>Extension</u>
<u>Care of Water</u>	1 lump sum		<u>155,000</u>
SUBTOTAL			155,000
 <u>Embankment</u>			
Foundation preparation & Core Trench Excavation	13,720 yds ³	2.30	32,000
Borrow Area Excavation & Haul - Impervious	342,250 yds ³	1.50	513,000
Compacted Embankment	332,200 yds ³	0.70	232,000
Embankment Filter & Drainage System	5,850 yds ³	16.00	94,000
Rock Riprap	13,500 yds ³	27.00	364,000
Granular Blanket, Below Riprap	10,130 yds ³	12.00	122,000
Miscellaneous Items	1 lump sum		<u>136,000</u>
SUBTOTAL EMBANKMENT			1,493,000
 <u>Spillway</u>			
Excavation & Haul			
- Rock	10,000 yds ³	5.00	50,000
- Other	80,500 yds ³	2.00	161,000
Reinforced Concrete	1,900 yds ³	400.00	760,000
Drainage System	1 lump sum		41,000
Miscellaneous Items	1 lump sum		<u>101,000</u>
SUBTOTAL SPILLWAY			1,113,000
 <u>Diversion & Permanent Outlet Works</u>			
Excavation	2,700 yds ³	2.70	7,000
Reinforced Concrete (Structural)	241 yds ³	600.00	145,000
Precast Pipe	426 lin.ft.	380.00	162,000
Concrete Bedding	387 yds ³	210.00	81,000
Control Gates & Hoists	2 gates	30,000	60,000
Miscellaneous Items	1 lump sum		<u>45,000</u>
SUBTOTAL DIVERSION & OUTLET WORKS			<u>500,000</u>
SUBTOTAL CONSTRUCTION			3,261,000
Contingencies (25%)			<u>815,000</u>
TOTAL CONSTRUCTION COST			<u>\$4,076,000</u>

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TABLE C7
Squaw Coulee Site 2
Preliminary Cost Estimate

	<u>Quantity</u>	<u>Unit Price</u>	<u>Extension</u>
<u>Care of Water</u>	1 lump sum		<u>112,000</u>
SUBTOTAL			112,000
 <u>Embankment</u>			
Foundation preparation & Core Trench Excavation	9,117 yds ³	2.30	21,000
Borrow Area Excavation & Haul - Impervious	275,360 yds ³	1.50	413,000
Compacted Embankment	220,560 yds ³	0.70	154,000
Embankment Filter & Drainage System	4,503 yds ³	16.00	72,000
Rock Riprap	8,655 yds ³	27.00	234,000
Granular Blanket, Below Riprap	6,491 yds ³	12.00	78,000
Miscellaneous Items	1 lump sum		<u>97,000</u>
SUBTOTAL EMBANKMENT			1,069,000
 <u>Spillway</u>			
Excavation & Haul			
- Rock	9,660 yds ³	5.00	48,000
- Other	2,420 yds ³	2.00	5,000
Reinforced Concrete	1,240 yds ³	400.00	496,000
Drainage System	1 lump sum		24,000
Miscellaneous Items	1 lump sum		<u>57,000</u>
SUBTOTAL SPILLWAY			630,000
 <u>Diversion & Permanent Outlet Works</u>			
Excavation	2,934 yds ³	2.70	8,000
Reinforced Concrete (Structural)	265 yds ³	600.00	159,000
Precast Pipe	466 lin.ft.	380.00	177,000
Concrete Bedding	424 yds ³	210.00	89,000
Control Gates & Hoists	2 gates	30,000	60,000
Miscellaneous Items	1 lump sum		<u>49,000</u>
SUBTOTAL DIVERSION & OUTLET WORKS			<u>542,000</u>
SUBTOTAL CONSTRUCTION			2,353,000
Contingencies (25%)			<u>588,000</u>
TOTAL CONSTRUCTION COST			<u>\$2,941,000</u>

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TABLE C8
Squaw Coulee Site 2A
Preliminary Cost Estimate

	<u>Quantity</u>	<u>Unit Price</u>	<u>Extension</u>
<u>Care of Water</u>	1 lump sum		<u>232,000</u>
SUBTOTAL			232,000
 <u>Embankment</u>			
Foundation preparation & Core Trench Excavation	18,620 yds ³	2.30	43,000
Borrow Area Excavation & Haul - Impervious	821,580 yds ³	1.50	1,232,000
Compacted Embankment	663,890 yds ³	0.70	465,000
Embankment Filter & Drainage System	8,416 yds ³	16.00	135,000
Rock Riprap	18,245 yds ³	27.00	493,000
Granular Blanket, Below Riprap	13,680 yds ³	12.00	164,000
Miscellaneous Items	1 lump sum		<u>253,000</u>
SUBTOTAL EMBANKMENT			2,785,000
 <u>Spillway</u>			
Excavation & Haul			
- Rock	56,840 yds ³	5.00	284,000
- Other	14,210 yds ³	2.00	28,000
Reinforced Concrete	1,764 yds ³	400.00	706,000
Drainage System	1 lump sum		33,000
Miscellaneous Items	1 lump sum		<u>105,000</u>
SUBTOTAL SPILLWAY			1,156,000
 <u>Diversion & Permanent Outlet Works</u>			
Excavation	3,965 yds ³	2.70	11,000
Reinforced Concrete (Structural)	331 yds ³	600.00	199,000
Precast Pipe	641 lin.ft.	380.00	244,000
Concrete Bedding	582 yds ³	210.00	122,000
Control Gates & Hoists	2 gates	30,000	60,000
Miscellaneous Items	1 lump sum		<u>64,000</u>
SUBTOTAL DIVERSION & OUTLET WORKS			<u>700,000</u>
SUBTOTAL CONSTRUCTION			4,873,000
Contingencies (25%)			<u>1,218,000</u>
TOTAL CONSTRUCTION COST			<u>\$6,091,000</u>

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LITTLE BOW RIVER BASIN
STORAGE SITE INVESTIGATION
CONCEPTUAL DESIGN REPORT
May, 1985

APPENDIX D

RESERVOIR DAMAGES AND LAND ACQUISITION

LIST OF RESERVOIR COST TABLES

<u>Site</u>	<u>Table No.</u>
Little Bow Site 1	01
Little Bow Site 2	02
Little Bow Site 3	03
Little Bow Site 7A	04
Mosquito Creek Site 3	05
Mosquito Creek Site 4	06
Squaw Coulee Site 2	07
Squaw Coulee Site 2A	08

TABLE D1
Reservoir Costs
Little Bow Site 1

Land Acquisition

Cultivation or Irrigation	700 ac. @ \$800	\$ 560,000
Grassland	300 ac. @ \$300	90,000
Severance (25%)		<u>170,000</u>
Total Land Cost		\$ 820,000

Roads

1. Section 2-18-27-W4		
Raise Existing Road		66,000
Slope Armouring		100,000
Bridge		300,000

Farm Buildings

3 Farm relocations @ \$50,000	\$ 150,000
TOTAL LAND AND RESERVOIR COST	\$1,436,000

TABLE D2
Reservoir Costs
Little Bow Site 2

Land Acquisition

Cultivation or Irrigation	1250 ac. @ \$800	\$1,000,000
Grassland	1550 ac. @ \$300	465,000
Severance (25%)		<u>365,000</u>
Total Land Cost		\$1,830,000

Roads

1. East Boundary Sec. 13-18-26-W4		
Relocate, construct 3 miles new road		300,000
2. East Boundary Sec. 12-18-27-W4		
Dyke Construction		3,000
3. South Boundary Sec. 25-18-27-W4		
Dyke Construction		38,000
Slope Armouring		30,000
4. South Boundary Sec. 26-18-27-W4		
Raise Existing Road		125,000
Slope Armouring		140,000
Bridge		300,000
5. East Boundary Sec. 27-18-27-W4		
Abandon		

Powerline

Special Long Span	100,000
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Farm Buildings

4 Farm Relocations @ \$50,000	\$ 200,000
1 Farm Relocation @ \$100,000	100,000

TOTAL LAND AND RESERVOIR COST	\$3,166,000
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TABLE D3
Reservoir Costs
Little Bow Site 3

Land Acquisition

Cultivation or Irrigation	1300 ac. @ \$800	\$1,040,000
Grassland	1000 ac. @ \$300	300,000
Severance (25%)		<u>335,000</u>
Total Land Cost		\$1,675,000

Roads

1. South Boundary Sec. 6-17-26-W4	
Raise Existing Road	150,000
Slope Armouring	200,000
Bridge	200,000
2. East Boundary Sec. 13-18-26-W4	
Raise Existing Road	200,000
Slope Armouring	120,000
Bridge	300,000
4. South Boundary Sec. 26-18-27-W4	
Raise Existing Road	100,000
Slope Armouring	110,000
Bridge	300,000
5. East Boundary Sec. 27-18-27-W4	
Abandon	

Farm Buildings

3 Farm Relocations @ \$50,000	\$ 150,000
TOTAL LAND AND RESERVOIR COST	\$3,505,000

TABLE D4
Reservoir Costs
Little Bow Site 7A

Land Acquisition

Cultivation or Irrigation	1300 ac. @ \$800	\$1,040,000
Grassland	1200 ac. @ \$300	360,000
Severance (25%)		<u>350,000</u>
Total Land Cost		\$1,750,000

Roads

1. South Boundary Sec. 5-15-25-W4		
Raise Existing Road		300,000
Slope Armouring		350,000
Bridge		300,000
2. Secondary Highway 529		
Raise Existing Road		300,000
Slope Armouring		300,000
Bridge		300,000
3. Sec. 26-15-26-W4		
Abandon		

Farm Buildings

6 Farm Relocations @ \$50,000	\$ 300,000
TOTAL LAND AND RESERVOIR COST	\$3,900,000

TABLE DS
Reservoir Costs
Mosquito Creek Site 3

Land Acquisition

Cultivation or Irrigation	100 ac. @ \$800	\$ 80,000
Grassland	675 ac. @ \$300	203,000
Severance (25%)		<u>71,000</u>
Total Land Cost		\$ 354,000

Roads

1. South Boundary Sec. 14-17-29-W4	
Raise Existing Road	250,000
Slope Armouring	200,000
Bridge	300,000
2. Farm Access Road	
Relocate	50,000

Farm Buildings

1 Farm Relocation @ \$75,000	\$ 75,000
TOTAL LAND AND RESERVOIR COST	\$1,229,000

TABLE D6
Reservoir Costs
Mosquito Creek Site 4

Land Acquisition

Cultivation or Irrigation	625 ac. @ \$800	\$ 500,000
Grassland	717 ac. @ \$300	215,000
Severance (25%)		<u>180,000</u>
Total Land Cost		\$ 995,000

Roads

1. South Boundary Sec. 2 & 11-17-29-W4		
Raise Existing Road		172,000
Slope Armouring		125,000
Drainage Pumpstation		100,000
2. North Boundary Sec. 11-17-29-W4		
Raise Existing Road		75,000
Slope Armouring		80,000
Bridge		200,000

Farm Buildings

2 Farm Relocations @ \$50,000	\$ 100,000
TOTAL LAND AND RESERVOIR COST	\$1,847,000

TABLE 07
Reservoir Costs
Squaw Coulee Site 2

Land Acquisition

Cultivation or Irrigation	30 ac. @ \$800	\$ 24,000
Grassland	690 ac. @ \$300	207,000
Severance (25%)		<u>58,000</u>
Total Land Cost		\$ 289,000

Roads

1. South Boundary Sec. 3-18-24-W4		
Raise Existing Road		300,000
Slope Armouring		320,000
Bridge		300,000
TOTAL LAND AND RESERVOIR COST		\$1,209,000

TABLE 08
Reservoir Costs
Squaw Coulee Site 2A

Land Acquisition

Cultivation or Irrigation	30 ac. @ \$800	\$ 24,000
Grassland	870 ac. @ \$300	261,000
Severance (25%)		<u>71,000</u>
Total Land Cost		\$ 356,000

Roads

1. South Boundary Sec. 15-18-28-W4		
Raise Existing Road		300,000
Slope Armouring		320,000
Bridge		300,000
2. South Boundary Sec. 3-18-28-W4		
Raise Existing Road		105,000
Slope Armouring		100,000
Bridge		200,000

TOTAL LAND AND RESERVOIR COST		\$1,621,000
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